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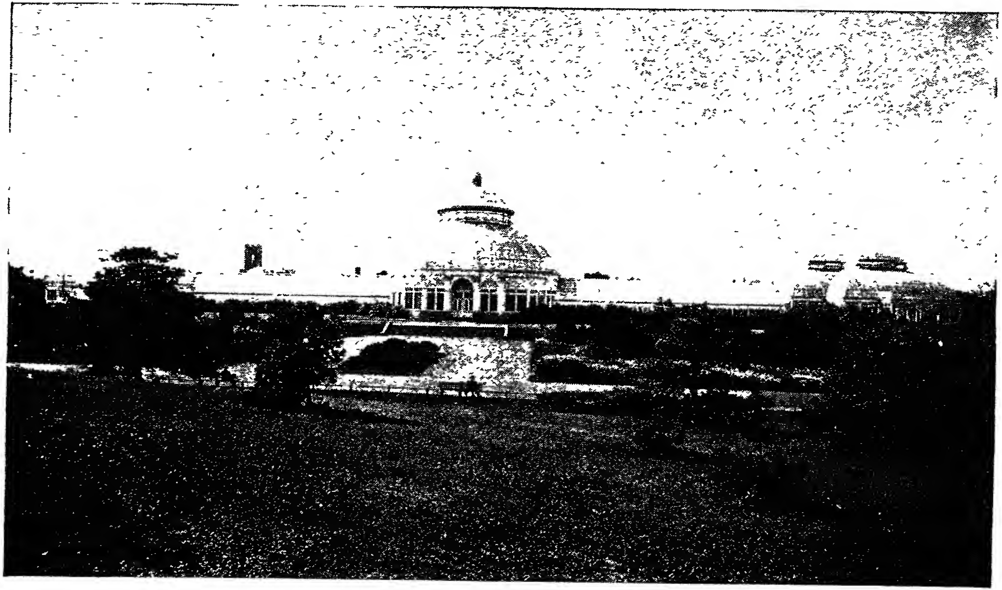
GREENHOUSES

THEIR CONSTRUCTION AND EQUIPMENT



Conservatory, New York Botanic Gardens.—*Courtesy Lord & Burnham Co.*

GREENHOUSES

Their Construction and Equipment

BY

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Revised Edition

ILLUSTRATED

LONDON

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To

MY FATHER

in whose flue-heated, shed roof propagating house I first learned to love the smell of the soil

PREFACE

Several years ago the author, at the request of Orange Judd Company, attempted to put into convenient form a comprehensive manual covering the construction and equipment of greenhouses and other like structures used for the growing of plants. It was based on a series of lectures given to various groups of students and supplemented by practical experience and by suggestions made by a number of friends and acquaintances engaged in growing flower and vegetable crops under glass.

Previously complete information on the subject was to be had only by consulting a variety of sources many of which were not readily available. A revised edition published in 1931 sought to include some of the more important improvements.

This third edition has been largely rewritten. There have been few if any changes in the application of fundamental principles to greenhouse construction in the past half century. There have been some changes in construction

and design. The greatest advances have been made in equipment especially in devices employing electric power which are automatic or semi-automatic in their operation and which tend to conserve time and labor. In this edition the author has tried to include a discussion of such of the newer devices and improvements as have been proven practical in actual use or which give promise of being of value in economic production.

It is practically impossible to give individual credit to all sources drawn upon in the preparation of this volume. Special mention is made of the cooperation of manufacturers of greenhouses and greenhouse material. Free use has been made of trade papers and the publications of the State Agricultural Experiment Stations and of the United States Department of Agriculture. Finally this third edition would not have been attempted had it not been for the many letters of appreciation and suggestion which have been received during the years since the original printing.

Ithaca, New York.

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GREENHOUSES

CHAPTER I

A GENERAL SURVEY

It is not the purpose of this book to furnish detailed information regarding the manufacture of greenhouse building material. This is the work of the mill and the factory. The purpose is rather to present such information regarding the location, adaptation, erection and equipment of greenhouses as will enable the reader to decide upon the structure best suited to his needs, select the material needed, erect or supervise its erection, and to arrive at some conclusion as to the equipment most likely to render the service required.

Greenhouses are an attempt on the part of man to create conditions favorable to the growth of plants in climates or during seasons naturally unfavorable. They must, therefore, protect the plants from cold and at the same time allow for an abundance of direct sunlight, provide for ventilation, and in most cases must

be equipped with facilities for artificial heating.

In meeting these conditions certain facts are to be kept in mind. 1. Heat, moisture and direct sunlight are necessary for the growth of commonly cultivated plants.* 2. The sun's rays provide both light and heat. It is economy to utilize both to the fullest, practical extent. 3. Heat rays from the sun pass through glass and other transparent materials. These rays warm the soil and the plants. On the other hand the heat radiated from the soil and plants does not pass back through the glass so readily. Hence a greenhouse becomes a trap to catch and utilize the heat and light rays from the sun. 4. Ventilation is necessary not only to provide fresh air, but to aid in controlling temperature. Heat from the sun alone may cause the house to become too warm at mid-day on bright, still days even in cold weather. 5. Warm air tends to rise, thus vents to control temperature are placed at or near the top of the house.

In a general sense the term greenhouse refers to a glass structure used for the growing of plants. They are for the most part above ground and are house-like in appearance. There is another type of glass stuctures used for the

* Plants may be grown under certain kinds of artificial light but it is not economy to depend on artificial light alone.

growing of plants but which are only a few inches above ground, thus requiring that the plants be cared for from the outside. They are commonly known as sashbeds, for the reason that certain standard size glass sash are used. They are limited in their use by the fact that the plants are exposed to the outside air when being cared for by the operator. This limits their usefulness to moderate climates, or in more severe climates, to the spring and fall seasons when there are days likely to be warm enough so that the plants may be exposed without injury.

TYPES OF SASHBEDS *

There are three general types of sashbeds; namely, hotbeds, coldframes and coldpits. Hotbeds are provided with artificial heat. Coldframes, in the strict sense, derive their heat from the sun only. Coldpits are deep pits used mostly for storing bulbs and hardy plants during the winter but are provided with a glass roof so the sunlight may be admitted on occasion.

TYPES OF GREENHOUSES †

There are three general types of greenhouses

* For details see Chapter II.
† For details see Chapter III and following Chapters.

as determined by their use; namely, forcing houses, conservatories and propagating houses. Forcing houses are those used for growing or "forcing" plants at other times than at their natural season. Practically all houses used by commercial florists and vegetable growers are forcing houses. Conservatories are houses in which plants are kept mostly for display. They are also used to house, during the winter, semi-hardy evergreen and other plants which are grown out-of-doors during the summer. They are common in parks and on private estates. They are ornamental in character, often circular in form and with curved roofs and present a lively contrast to the severe simplicity of the commercial forcing house. Propagating houses are devoted largely to the starting of plants, especially those grown from cuttings. As cuttings require less direct sunlight than most growing plants propagating houses are often erected on the north side of other greenhouses. They are equipped with benches underneath which the heating pipes are placed to provide "bottomheat."

The term hothouse as commonly used is a general one synonymous with greenhouse and may be applied to any of the above types.

The term stovehouse is an old one, originally

applied to any greenhouse used for growing tropical plants and thus of necessity kept at a high temperature. The use of this term is more common in England than in this country.

A range of glass implies several houses more or less closely connected and under one management. The individual houses may be of any type or any combination of types. A range of forcing houses is sometimes spoken of as a battery and a range of sashbeds as a nest.

EVOLUTION OF THE GREENHOUSE

It is said that the Romans even before the time of Christ possessed some knowledge of the forcing of fruits and vegetables and utilized for this purpose pits or cellars covered with slabs of a transparent mineral. Heat was supplied by fermenting manure or occasionally by furnaces of masonry in which a slow fire was kept burning. How successful they were we do not know; but it seems certain that if any degree of perfection was attained it was because of the skill of the gardener rather than because of any merit of the pits as compared with the modern greenhouse.

Forcing houses seem to have had their origin in an attempt to grow, in northern countries,

fruits such as the orange and the grape which are grown to perfection in the south. Thus in England the grape is hardy, but the summers are too cool and the season too short to ripen the fruit to perfection. This led to the training of the vines on the south side of buildings and walls so that they might receive more fully the light and heat of the sun and might profit by the heat stored up in the walls. Later they were further protected by leaning glass sash against the walls. From there it was an easy step to the building of a permanent framework close to the walls on which the sash were placed, forming a closed house. Sometimes the walls were made hollow and slow fires started within them to give additional heat. Finally the idea of heating the air resulted in the building of stone fireplaces within the glass enclosure. These houses were not intended for winter use but simply to make the summer and fall conditions similar to those farther south.

The attempt to grow the orange in northern climates presented a different problem because the trees had to be protected during the winter. This resulted in the building of framework structures which were covered during the winter with wooden shutters and heated by means of stone fireplaces. Little or no glass was used

but the shutters were removed during the summer leaving nothing but the framework to obstruct the heat and light from the sun. A house of this description, built early in the seventeenth century by one Solomon de Gaus at Heidelberg, Germany, is said to have been 32 feet wide and some 400 feet long and to have sheltered 400 small orange trees.

The next decisive step in the evolution of the greenhouse seems to have been a combination of the two preceding types and designed for the growing of plants during the winter. They were permanent buildings having opaque roofs and high side walls, resembling dwelling houses except that they were well supplied with side windows.

At this time it was thought necessary to have opaque roofs to prevent freezing, and it became the custom to have a second story, which was used as a dwelling by the gardener. This was supposed to prevent the heat from escaping or the frost from "entering" through the roof. It was not until the early part of the 18th century that glass roofs were found to be practicable and even then they were slow in coming into use.

The first greenhouses in this country suggestive of the modern forcing house came in to-

ward the close of the 18th century. For the most part they were narrow houses of the shed-roof type, having a solid wall to the north and a glass roof sloping toward the south. They were warmed by means of flues, usually of brick passing through the house from a fire-place placed outside. Following this there came in rapid succession, improvements in form and in methods of construction, especially in heating. Both steam and hot water were used for heating in the early eighteen hundreds.

The real progress in greenhouse construction in this country came with the industrial development after the Civil War. The United States census reports show that there was but one commercial greenhouse prior to 1800; only three prior to 1820, and only 178 in 1860. It was not until 1890 that greenhouses had assumed sufficient importance to receive statistical mention in the census reports. At that time there were 4,659 establishments covering 38,823,247 square feet, valued at $38,355,722 or a little less than $1.00 per square foot. By 1909 there were 114,665,276 square feet under glass of which 105,165,730 were in greenhouses and about 9,500,000 square feet were hotbeds and coldframes. The 1939 census shows 205,114,773 square feet under glass but does not show

what proportion was in greenhouses. Observation would tend to indicate that the proportion in greenhouses is greater now than 30 years ago. The use of hotbeds has decreased and the use of coldframes has increased.

At the time of the Federal census of 1939 the East North Central States led in the value of crops grown under glass followed by the Middle Atlantic States, New England, West North Central, Pacific, South Atlantic, West South Central, East South Central, and the Mountain States in the order named. The distribution is determined to a considerable extent by the local demand, by climate, and by transportation facilities. It does not necessarily indicate that individual profits are greater in any one geographical area. Both flowers and vegetables are shipped long distances in refrigeration and experiments are now under way with shipments by airways.

CHAPTER II

SASHBEDS

Since sashbeds are relatively inexpensive and are likely to be the first structures to be used by amateurs in growing plants under glass their construction and operation will be discussed before considering the more expensive greenhouse.

Location.—Before starting construction it will be well to consider the site or location. A suitable location may well spell the difference between success and failure. The following are some of the factors to be considered: 1. The site should be high enough to be free at all times from standing water; 2. It should be well drained, either naturally or artificially; 3. It should be exposed to direct sunlight throughout the day; 4. It should be protected from north winds; 5. It should be level or slightly sloping toward the south or southwest.

For convenience it should be near some heated building which can be used as a workroom and should be convenient to a supply of

water. The south side of a building is often a good location though the beds should be placed far enough away so that they will not be damaged by ice and snow falling from the roof.

There are two essential structural parts of sashbeds; a sash of glass or other transparent material, and a frame to inclose the plants, keep

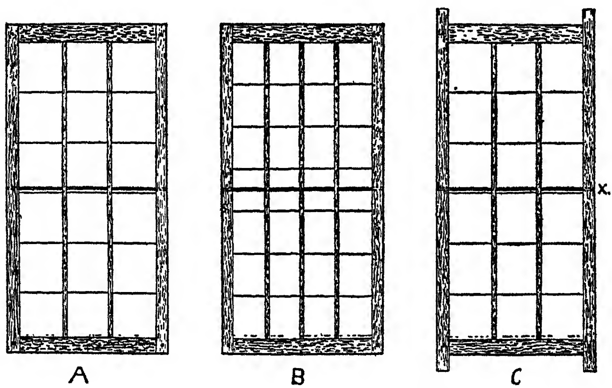


Fig. 1.—Standard Hotbed Sash
A, three run sash; B, four run sash; C, Horned sash; X, iron rod to keep sash from spreading.

out the cold and on top of which the sash rest. Custom and experience have resulted in the standardization of form and size. Standard sash (usually known as hotbed sash though the same are used for all kinds of sashbeds) are 3 x 6 feet in size. (Fig. 1). The frame may be made to accommodate one or any number of

sash. Since the sash are placed so that they will slope lengthwise to the south the width of the frame is 5 ft. 11 in. north and south, outside measurement, and as long as necessary to take care of the number of sash to be used. The length will be 3 ft. or any multiple of three. When two or more sash are used they are sup-

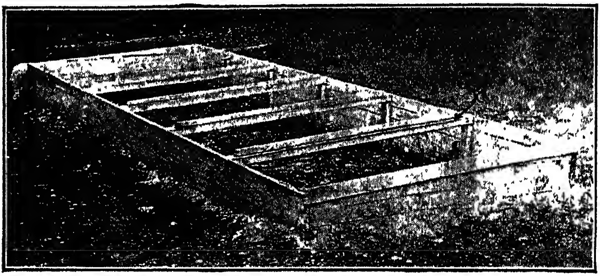


Fig. 2.—Coldframe with sash removed. The sash rest on the crosspiece, X.

ported lengthwise by crossbars connecting the sides of the frame and spaced every three feet, being fastened so that they are flush with the top of the frame. (Fig. 2). Many growers prefer to separate the sash by placing a strip about an inch wide on the top of the crossbars as high or higher than the thickness of the sash. In this case the frame must be made longer than an exact multiple of three to allow for the width of these strips. Also allow about half an inch

leeway between sash and dividing strips to prevent the sash from binding. A special type of crossbar or rafter designed to separate the sash and to carry off water that may seep down between the sash is shown in Figure 3.

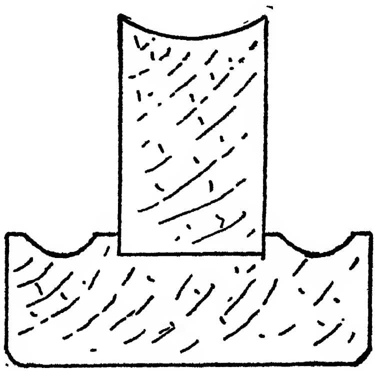


Fig. 3.—Crossbar or rafter with concave top, and gutters to carry water to side of frame.

The frame is made so that the sash will slope slightly in order that the water from rain and melting snow, and also the water which condenses on the under side of the sash, will run toward the edge of the bed. They are placed to slope to the south so they will trap more of the light and heat rays of the sun. To provide for this slope the frame is made so that it is about six inches higher on the north side that

on the south. The usual height is 12 inches on the north and six inches on the south. Rot resisting lumber is used for the frame since the conditions to which it is exposed make for rapid decay. Cypress is undoubtedly the best material for sashbed frames but if this cannot be had cedar is the next best. If neither can be had pine or almost any kind of lumber will give satisfactory service if it is treated to resist decay with a wood preserving material. For directions see Chapter V.

Sash.—Standard sash are from 1⅜ to 1¾ inches thick, the thicker being the more durable but are heavier to handle. As in the case of frames cypress is undoubtedly the best material, but other kinds of wood are frequently used. However, sash being the most expensive part of the equipment, and being subject to much handling and hard usage it is economy to buy only well made sash of good material. Well constructed sash can be had from any reliable dealer in greenhouse material. It is doubtful economy to make sash at home unless one is an experienced carpenter and even then the time consumed in the necessary hand labor is likely to be more valuable than the saving in the cost of the sash. Sashbed sash, like window frames and sash, are made by means of special machin-

ery by skilled workmen on a quantity production basis. Sash with a light iron tie rod connecting the side bars are preferred as the rods prevent the sides from spreading and thus loosening the glass. (X, Fig. 2).

Most sash consist of three rows of 10 x 12 inch glass. This requires 18 panes of glass for each sash. Sash having four rows of glass are not uncommon but the extra bar and laps obstruct so much sun that they are less satisfactory. They are rapidly going out of use. Such sash require 28 panes of 8 x 10 inch glass.

It is advisable to use only standard size sash. Experience has shown them to be the most satisfactory. Pony or junior sash (2 x 4 ft.) and half sash (3 x 3 ft.) are sometimes used but have little to recommend them. Their only desirable quality seems to be that they are lighter in weight and therefore are easier to handle. Sash over 3 x 6 ft. are too heavy for economy in handling and are likely to warp or twist thus loosening or breaking the glass.

A form of sash known as "horned sash" (C. Fig. 1) are preferred by some. It is claimed for them that they are easier to handle and that a stronger frame can be made when the side bars extend beyond the ends.

Double Glass Sash,—as the name implies,

are made with two layers of glass with an air space between them (Fig. 4). They have certain qualities which make them superior to single glass sash which may be stated as follows: 1. They give more protection from cold; 2. They save labor since it is not necessary to give sup-

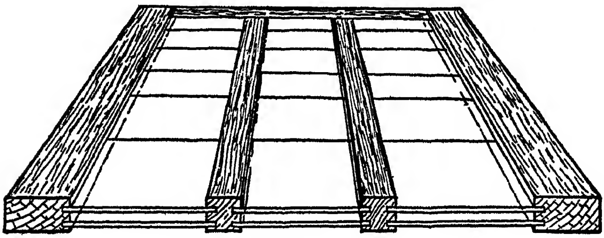


Fig. 4.—Double Glass Sash

plementary protection in moderately cold weather; 3. Plants receive sunlight during the entire day whereas with single light sash, in cold weather, supplementary protection must be given from late afternoon to late morning thus shading the plants for several hours.

On the other hand double glass sash have several disadvantages; 1. The first cost is often as much as 50 percent greater; 2. They are heavier to handle; 3. They reduce the amount of light and heat, especially if the glass becomes loosened so that dust accumulates between the layers; 4. Some growers complain that they are

short lived since moisture tends to collect between the layers of glass and promotes rapid decay of the wood.

The most enthusiastic users of double glass sash are those who live in mild climates or who use them at seasons of the year when no supplementary protection is needed but where it is not safe to leave single glass sash unprotected.

Glazing.—While it is not recommended that growers attempt to make their own sash it is often economy to glaze them thus saving in first cost and in transportation. When sash are glazed at home they should first be primed with a coat of thin, preferably white, paint. If they have been primed when received it is not necessary to give another coat. On looking them over it will be observed that one of the end bars is thinner than the other, the upper surface being in line with the bottom of the channels made to receive the glass. This is the lower end of the sash which should always be placed toward the south and at which end the glazing is begun. In glazing the first pane is laid flat, the bottom of the second being lapped over the top of the first and so on, small brads or glazing points being driven at the lower end of each pane and along the sides to hold them in place. Since the lap obstructs the light it should be narrow, an

eighth of an inch being as wide as necessary. It is well to lay all the panes for one row on loosely before fastening so as to get the spacing even. After fastening they are puttied the same as window glass, and the whole thoroughly painted.

A more satisfactory way of setting glass is to bed them in putty as described in Chapter VII, but this method is rarely used with sash-bed sash. Sometimes the glass are butted; that is, they are laid flat end to end instead of lapped. This is rarely satisfactory for sashbed sash; because, if the panes are not squarely cut heat escapes, and the sash have so little slope or pitch that water runs through between the ends of the panes.

Some use no putty on sashbed sash but simply fasten the glass in with glazing points. This is doubtful economy.

HOTBEDS

Hotbeds are a type of sashbed in which some form of artificial heat is installed and which may be used in any season or climate if there are occasional days warm enough to permit the sash being removed for watering and other attention. Their chief commercial use is for

starting early vegetable and flowering plants, or for starting cuttings in summer. In the home garden they may be used for growing to maturity in both spring and fall such semi-hardy and quick growing crops as lettuce and radishes and thus extend the season for these crops by several weeks or even months. They may also be used for starting and protecting, early in the season, such heat loving crops as melons or tomatoes which are not transplanted but are allowed to mature in the beds, the sash being removed when warm weather arrives. A gain of several weeks may thus be gained in the time of ripening. In the hands of a skillful operator hotbeds give excellent results but they require constant care.

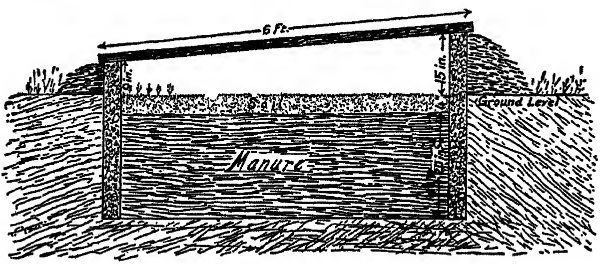


Fig. 5.—Plan for permanent hotbed.

Hotbeds were originally heated by decaying vegetable matter, usually horse manure. Because of the growing scarcity of horse manure

and the development of other and more easily controlled means of heating, manure heated hotbeds are less common than formerly.

Manure Heated Hotbeds.—Since horse manure, when it may be had, is a fairly satisfactory and inexpensive source of heat for hotbeds the following directions are given for their construction. Some other form of heating may be installed later if desired.

Since considerable depth of manure is needed to provide sufficient heat the first requirement is a pit of the right size. The dimensions will be determined by the number of sash to be used. The depth will be determined by the severity of the climate and the kind of plants to be grown. As more heat is produced for a longer time from a deep pit than from a shallow one it is evident that for cold climates and for plants requiring considerable heat the pit must be deeper than in warmer climates or for plants requiring less heat. For starting early vegetable plants in late February or early March in the north from 24 to 30 inches of manure is needed whereas in milder climates or later in the season from 12 to 18 inches is sufficient. The manure will provide heat for from three to six weeks depending on the depth and the quality of the manure.

The pit may be dug, lined with lumber or concrete to the surface of the soil and a sashbed frame placed above it. If it is to be permanent it is best to construct it so that the lining of the pit, whether of lumber or concrete, extends

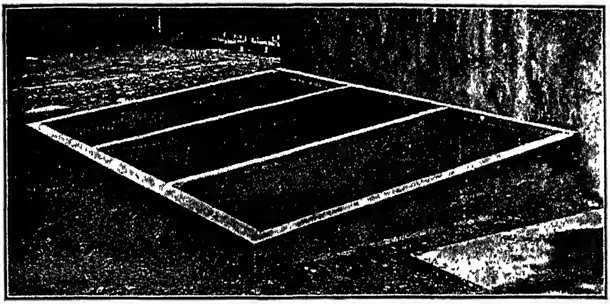


Fig. 6.—Usual type of concrete hotbed.

above the surface to form a frame as shown in figures 5 and 6. The depth is determined by the amount of heat required as described above. Allow four or five inches for soil on top of the manure and an inch or more for the plants to grow. Thus if 24 inches of manure is required the bottom of the pit will be 29 or 30 inches below the sash on the south side. The manure will settle three or four inches as it gives off heat thus providing extra space for the plants to grow. If less manure is used allow more space for the plants as the shrinkage of the ma-

nure will be correspondingly less. It is always wise to allow for more manure than seems actually necessary than to allow for less. It is of utmost importance that the frame be solid and substantial so that the sash will fit snugly. Otherwise much valuable heat will be lost. The sides of the frame above ground are banked with soil or preferably with manure to prevent loss of heat.

It sometimes happens that a hotbed is decided upon in early spring before the frost is out and when a pit cannot be conveniently dug. In this case a temporary bed may be made by piling properly prepared manure in layers on the surface of the ground somewhat larger than the size of the hotbed frame. The frame is then placed on top of the pile of manure. Such hotbeds are not entirely satisfactory, especially in cold weather for the frame is likely to warp as the manure settles and the sash will not set properly.

Preparation of Manure.—Use fresh horse manure in the proportion of two parts excrement to one of straw. Manure which contains shavings is not satisfactory. Prepare the manure 10 to 12 days before time for sowing the seeds. Prepare more than enough to fill the pit to provide for shrinkage. Dampen slightly

with warm, not hot, water, mix thoroughly and place in layers in a pile about four feet high under cover if possible. Tramp each layer lightly as it is placed. After two or three days, or as soon as the pile begins to steam, repile placing the outside in the center of the new pile to encourage even fermentation. Moisten with warm water if it has become dry. A vigorous fermentation should set in two or three days after repiling and it is then ready to be placed in the pit. If it has not fermented vigorously repile as before.

When fermentation is satisfactory place the manure in the pit in thin layers tramping each layer until quite solid especially along the sides and in the corners, keeping it level. Then put on the soil. The temperature will soon rise to 120 degrees or more but will gradually fall and

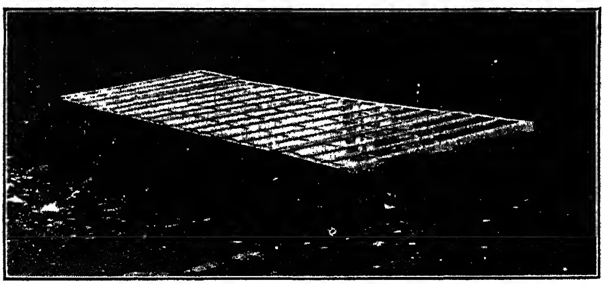


Fig. 7.—Hotbed in operation.

when it reaches 90 degrees the seeds may be safely sown. If plants are to be grown in flats only two inches of soil need be placed over the manure and the flats set on the soil.

Properly constructed manure heated hotbeds with suitable protection above the sash will withstand a temperature of zero if of short duration. For a discussion of supplementary protectors see page 35.

While horse manure is considered the best organic matter for producing heat in hotbeds sheep manure is sometimes used, also shredded corn stalks from the feed lot.

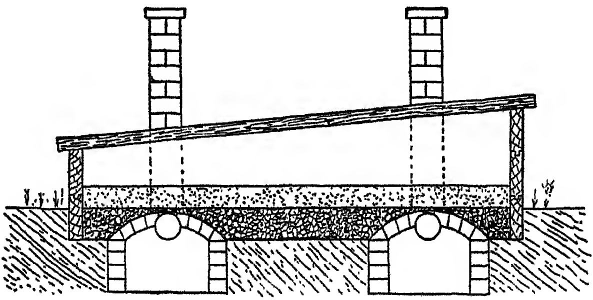


Fig. 8—Hotbed arranged for heating by flues.

Other Methods of Heating.—An arrangement for heating a hotbed by means of flues is shown in figure 8. A furnace of some kind is

placed at one end of the bed and a chimney at the other. They are connected by tile flues placed a few inches below the soil and sloping slightly upward from the furnace to insure a draft or circulation. The part of the bed nearer to the furnace will be warmer than the one at the chimney as the gasses give up some of their heat as they travel. This is especially noticeable where a number of sash are used and the bed is a long one. For even distribution of heat two flues are better than one though both may be connected to one furnace and one chimney rather than having two separate ones as illustrated. It takes infinite care and patience to achieve satisfaction with this type of heating though they are quite common in some sections. Many modifications are possible. An old oil drum may be used as a furnace and the flues turned up to act as chimneys by using an elbow.

When steam or hot water is used for heating no pit is required. They are most commonly used in connection with greenhouses where steam or hot water is available. The heating pipes may be buried beneath the soil or they may be hung along the sides of the frame. For arrangement of piping and amount needed see Chapters XI and XII. One great advantage of hot water or steam is that

the heat may be controlled by means of a thermostat.

Although somewhat in the experimental stage electricity seems likely to provide the best means for heating hotbeds especially for the amateur. They are being used commercially. Temperature control in electric heated hotbeds may be even more positive and satisfactory than with steam or hot water heating.

Some have had good results by using ordinary electric light bulbs and reflectors placed along the sides of the frames and connected with a thermostat, and have felt that in addition to the heat given off by the lamps the light made for a better growth of plants. Others have used small electric heating units centrally located. It now appears that the most satisfactory method is to use a moisture-proof heating cable. The general practice is to place the cables as shown in figure 9 and to cover them with from four to six inches of soil in which the plants are grown. In some cases the cables are placed along the sides of the frame. Some prefer to place the cables just underneath the surface of the soil. If so placed they interfere to some extent in weeding and transplanting but it is claimed that the heating is more efficient. Some growers equip their coldframes with these heat-

ing cables as a method of insurance, using them only should the temperature fall below the danger point.

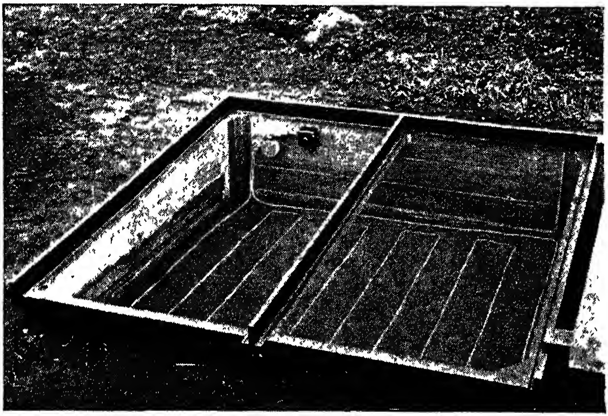


Fig. 9.—Hotbed arranged for heating by electric cables.—*Courtesy General Electric Co.*

In figure 10 is shown an arrangement for utilizing heat from the basement of a furnace heated dwelling for heating a hotbed. It may only be necessary to remove a basement window and build a frame close against the basement wall. Rather elaborate structures of this kind have been built by tearing out a portion of the basement wall so that the plants may be tended from the inside. If there is sufficient heat plants may be grown in these structures during the

entire winter. Heating may be aided by using an electric fan so located as to circulate warm air into the structure.

In this discussion of artificial heating it may be well to again remind the reader that light is just as necessary as heat for the development

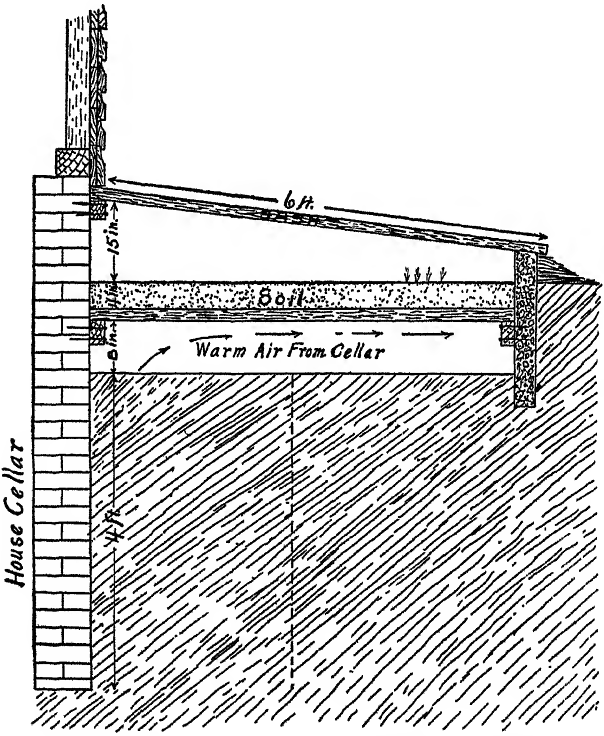


Fig. 10.—Sash-bed attached to basement of dwelling.

of cultivated plants which accounts for the use of glass or other transparent materials; also that these materials tend to trap the sun's rays to such an extent that on bright sunny days even when the temperature is below freezing the hotbed may become excessively warm. Since the hotbed contains relatively little air close attention to the regulation of the heat by ventilation is necessary. This is accomplished by raising the sash at one, usually the north, end or by sliding some of the sash either down or up. With the high winds prevailing when hotbeds are most used it is necessary to provide some method of holding the sash to prevent their being blown off the frames.

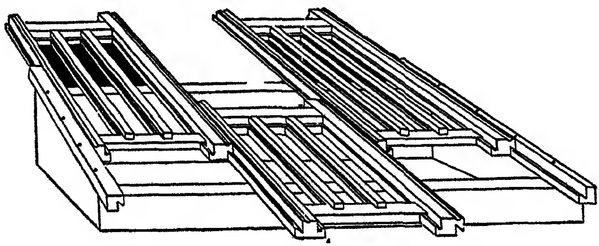


Fig. 11.—Patented Interlocking Sash.

In figure 11 is shown a form of patented sash which are locked together so that they need no supporting bars and for which it is claimed that, since they are locked together, ventilation

may be had by sliding some of the sash upward or downward without danger of their being blown off as with ordinary sash.

COLDFRAMES

The forcing house, because of its convenience, ease of heat regulation and because work may proceed in all kinds of weather is rapidly taking the place of the hotbed in a commercial way for the starting of early plants but it is promoting the use of cold frames. These rarely receive artificial heat but rely solely on the heat of the sun. They are used largely for growing and protecting plants in late spring after they have been started and transplanted into flats in the greenhouse or hotbed. Since 10 to 20 times as much space is required for plants after transplanting as when first sown the use of the relatively inexpensive coldframe makes it possible to produce plants much more cheaply than when the more expensive greenhouse space is used to grow them until they are ready for the field.

Coldframes are simply hotbeds without artificial heat. No pit is required, the frame being placed on the surface of the ground. (Fig. 12). When properly constructed, banked with earth or manure, and protected on cold days with

mats they are safe for plants even at temperatures of 15 to 20 degrees below freezing if of short duration. They absorb the heat of the sun during the day and are covered to prevent its rapid radiation during the night.

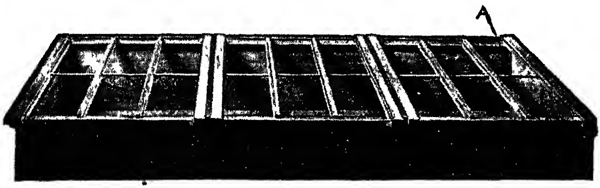


Fig. 12.—A good type of coldframe with angle iron corners, A.

When considerable space is needed in relatively mild weather temporary coldframes are made by placing planks parallel to each other 5 ft. 11 in. apart, outside measurement, the plank on the north side being about 12 inches wide and the one on the south 6 inches wide. Crosspieces are then nailed flush with the tops to support the sash and the frames banked with earth. Care is taken to see that the planks are level so that the sash will fit snugly. When the plants are removed the planks may be taken up and stored and the space used for other crops.

COLD OR STORAGE PITS

In almost every florist establishment there is need for an out-of-the-way frost proof storage, to which light may be admitted on occasion. These pits (Fig. 13) are deep enough so that

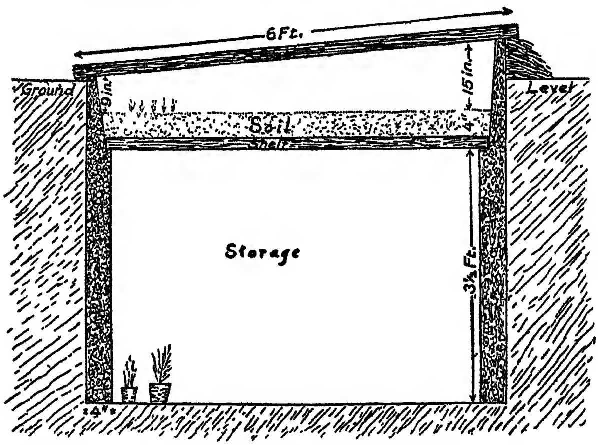


Fig. 13.—A cold or storage-pit with shelf for growing violets.

the bottom is well below the frost line and thus receive a certain amount of heat from the soil. If the surface soil is well mulched for two or three feet around the pit and the sash covered in very cold weather they are frost proof but not warm enough to promote much growth in winter. They are excellent for storing bulbs.

FORCING BOXES

Forcing boxes or plant forcers are small cold-frames with a single pane of glass or glass substitute which are used to place over individual plants after they have been planted in the field in early spring. (Figs. 14 and 15). They are

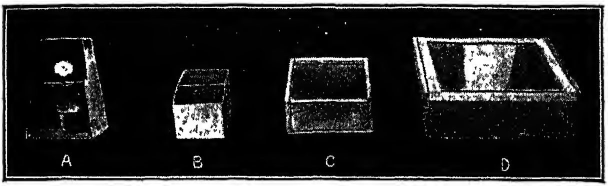


Fig. 14.—Types of forcing boxes or plant forcers.

Fig. 15.—Forcing boxes in use on a commercial scale.

used for heat loving plants in order to give them more warmth. They are removed as soon as continuous warm weather arrives. They are

also used for forcing rhubarb and asparagus in early spring and for perennial flowering plants. Another type of plant forcer popularly known as a "hotcap" is made of parafined paper in the form of a cone or dome. It is semi-transparent and is provided with a flange over which soil is placed to keep it in place. They may be placed rapidly and while they are seldom used for more than one season their first cost is such as to compare favorably with the more expensive and longer lasting types. They do not allow as much light to pass through as does glass but for protecting plants for short periods are satisfactory.

GABLE-ROOF SASHBEDS

Sometimes hotbeds and coldframes are made of two rows of sash set so as to form a gable as

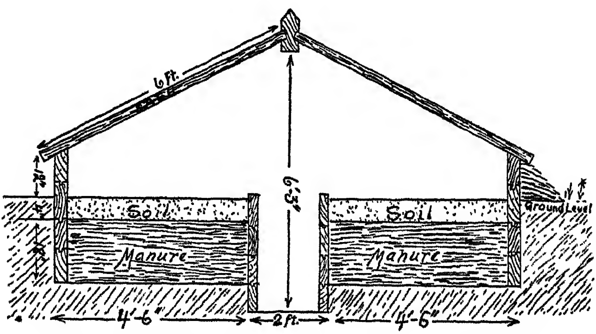


Fig. 16.—Gable roof sash-bed heated by manure.

shown in figure 16. They are an improvement over the low type of sashbed in that the operator can work from the inside. When an investment has been made in a house of this type it will be economy to equip it with an inexpensive hot water heating system. The extra expense of making an unheated house of this type is unwarranted as ordinary coldframes can be used about as easily.

MATS AND SHUTTERS

Hotbeds and coldframes, when used in cool weather as they usually are, must be provided with some supplementary coverings. This is especially true when single glass sash are used.

Rye straw mats (Fig. 17) are extensively used for this purpose. Each mat is designed to cover two sash and is 6 x 7 feet in size to allow for turning over the ends to help to keep out cold winds. An objection to straw mats is their weight especially when wet. Mice also work in them when stored unless they are permeated with some substance such as tar or creosote. With careful handling they will last for several years.

Burlap and canvas mats, which are padded with waste cotton and quilted are easier to

handle than straw mats and are somewhat more durable. Though thinner than straw mats they give equally as good protection. They have the added advantage of requiring less storage space.

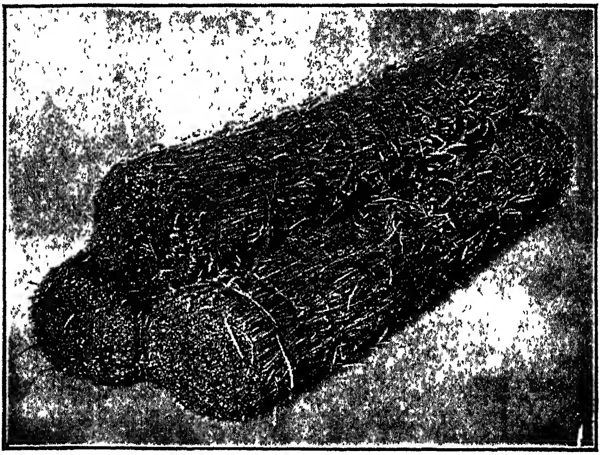


Fig. 17.—Rye straw mats rolled for storage.

Waterproof mats of heavy canvas, or sometimes of oiled or rubberized fabrics seem to have little advantage over common mats though some use them over coldpits. They are relatively expensive.

Wooden shutters, 3 x 6 feet in size made of half-inch lumber are occasionally placed over mats. They help to keep the mats from being blown off and give some extra protection. Shut-

ters made of insulating board are now quite commonly used but are shortlived unless kept carefully painted.

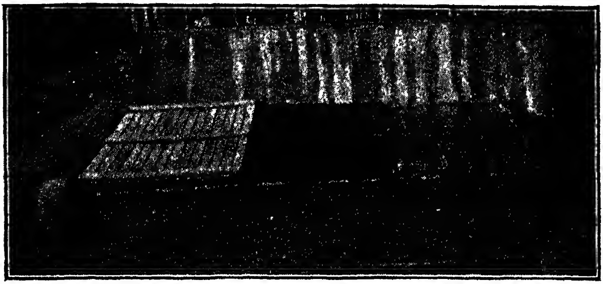


Fig. 18.—Hot-bed covered with (C) double glass sash; (B) sash and straw mat; (A) sash, straw mat and shutter.
shutter.

Care of Sashbed Materials.—As hotbeds, coldframes and the like are used for only a few months during the year they are likely to be neglected and to deteriorate rapidly. When many are used their proper care will help to keep the expense within bounds. If frames are easily taken apart it is well to do so and store them flat under cover. If not they may be cleaned, stacked and painted.

Sash, being an expensive part of the equipment, deserve special care. They should be put under cover as soon as the season is over. Rainy days may be utilized in repainting and

reglazing as necessary. It is advised that sash be painted every year.

Mats must be thoroughly dry when stored, and be protected from mice and rats.

Glass Substitutes.—Several transparent or semi-transparent materials are now on the market which are used as substitutes for glass. They are mostly celulose products. They are much lighter in weight than glass and less expensive and since they may be had in rolls about three feet wide it is only necessary to tack them to the sash instead of glazing. It is not necessary to use as heavy a sash as when glass is used, any substantial frame across which two or three wires are stretched to support the fabric being all that is necessary. It is best to use a binding of metal or thin wooden strips along the sides when fastening the material to the frame to prevent tearing out.

The author's experience with these glass substitutes has not been entirely satisfactory. They seem to stain easily and collect dirt both of which are difficult to remove. They are also less sturdy than glass and are easily torn. Those made on wire screen are more durable than others. They are fairly satisfactory for use on sashbeds but are not recommended for greenhouses. The claim sometimes made for them

that they are better than glass because they allow more of the ultra violet rays of the sun to pass through than does glass is not well founded as ultra violet light is not essential to plant growth.

Muslin and canvas are sometimes used as a covering for coldframes in climates or at a time of year when the plants are expected to need only occasional protection. They are not substitutes for glass but are used largely for protection on cold nights or on unusually cold days. Instead of being used on sash one end or side is nailed to the north side of the frame and the other edge to a roller so that they can be easily rolled up out of the way when not needed. These cloth protectors are sometimes made more or less waterproof by treating them with the preparations used for water proofing tents.

CHAPTER III

THE GREENHOUSE PROPER—GENERAL CONSIDERATIONS

Location.—Having determined upon the geographical location, proximity to market and fuel supply and the investment in land which the business may be expected to warrant, all of which are without the scope of this discussion, the points next to be considered in the location of a greenhouse are as follows: (1) It should be such that the sunlight will not be obstructed at any time during the day. The probability of high buildings being erected in the immediate vicinity should be taken into account. (2) It should be well drained either naturally or artifically and be absolutely free of danger from floods. (3) It should not be exposed to cold, bleak winds, as they will quickly make their presence known in excessive fuel bills. A wind break of evergreen or other trees will be found very effective in protecting from winds but it will be several years before the trees will be large enough to be of much benefit. (4) It

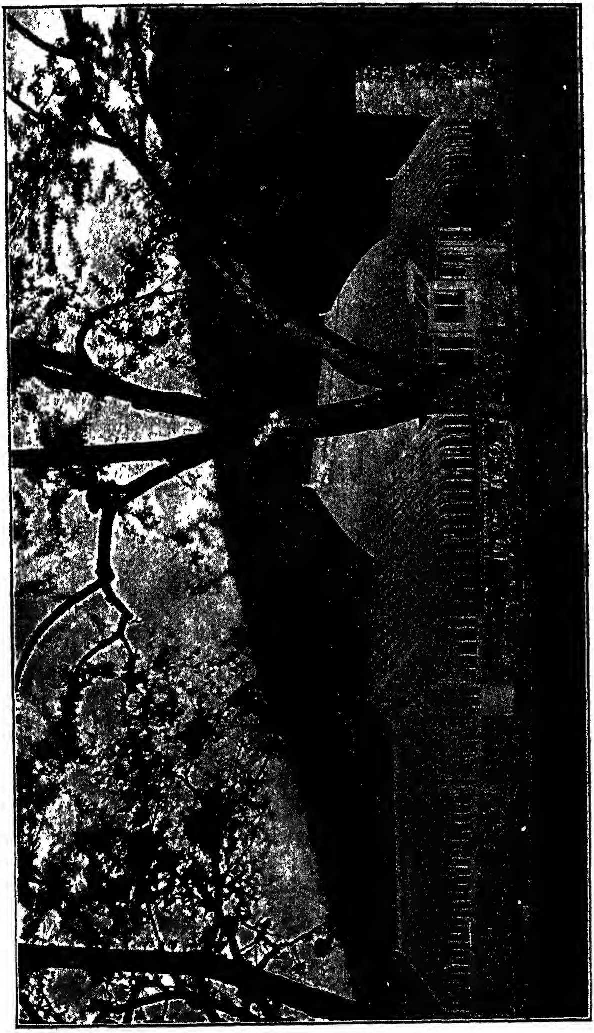


Fig. 19.—Private range or conservatory.

should be comparatively level, or gently sloping toward the south or southeast. Hillsides, if necessary, may be utilized by building houses of special design to be described later. (5) An unfailing supply of water at a reasonable cost should be assured. (6) If the houses are to be erected in connection with other buildings, they should be on the south side if possible. For most plants the advantage of direct sunlight during the whole day cannot be over-estimated. (7) The possibility of enlarging the range by the addition of more houses should not be overlooked..

Arrangement.—The arrangement will depend to some extent on the size of the range and the purpose for which it is to be used. If for private use only, convenience may often be sacrificed for appearance; but for the commercial house the first thought in arrangeemnt is for economy in operation.

For a commercial house the following points in arrangement should be considered: (1) The direction in which the houses are to run. This will be fully discussed in Chapter IV. (2) The distance between the houses. This will depend on the size and height of the houses and on the value of the land. Little advantage, except in case of heavy snowfall, will be gained over the

Fig. 20.—A typical commercial range.

ridge-and-furrow system (see Chapter IV) by separating the individual houses by less than 10 or 12 feet. A fair though not absolute rule is to space the houses at a distance equal to two-thirds their height. (3) The workroom should be convenient to all houses of the range, yet shade them as little as possible. (4) Other things being equal, the boiler room should be at the lowest part of the range in order to secure good circulation. When the houses are long it is usually best to have it near the center, and to insure circulation by deepening the boiler pit, or in large establishments by the use of pumps or steam traps which will be discussed in the chapters on heating.

Size of House.—There is no authentic data on the comparative efficiency of small and large houses. The large houses are relatively lighter,

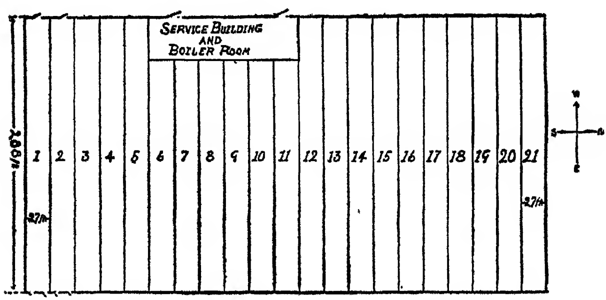


Fig. 21.—Ground plan of range shown in Fig. 20.

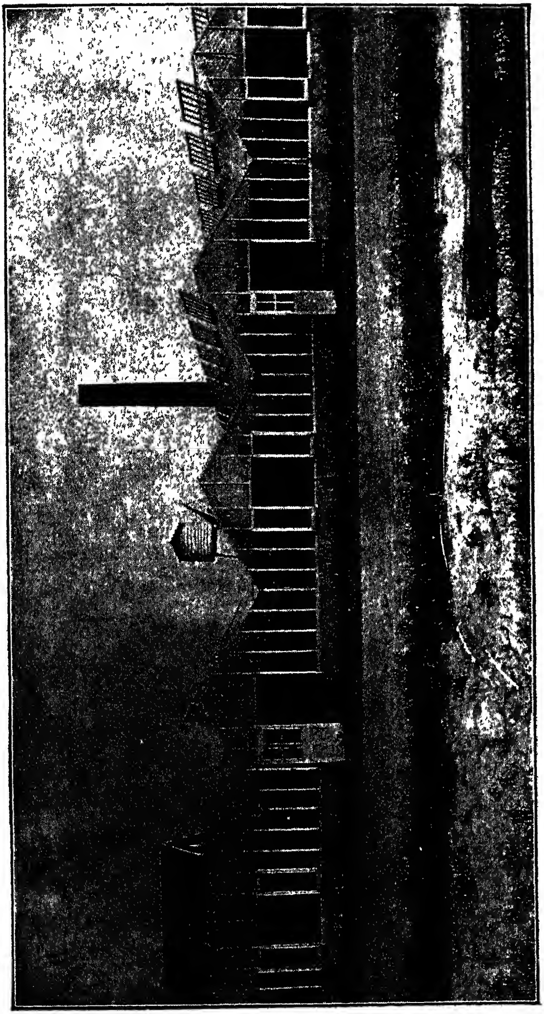


Fig. 22.—Part of a vegetable forcing range showing narrow connected houses.

but there are other considerations. The present tendency is to build larger houses than formerly. Of 160 florists and vegetable growers whom the author has consulted, 148 or 88 per cent. expressed themselves in favor of houses ranging from 24 to 40 feet in width. These are undoubtedly the most popular widths at the present time, the length varying from 100 to 500 feet or more. A discussion of the advantages of high, wide, single houses and of low, narrow, connected houses is given in Chapter IV.

Pitch of Roof.—The pitch of a roof means the degree of slant or the angle of divergence from the horizontal. The glass of the roof not only allows the light, heat and chemical rays to

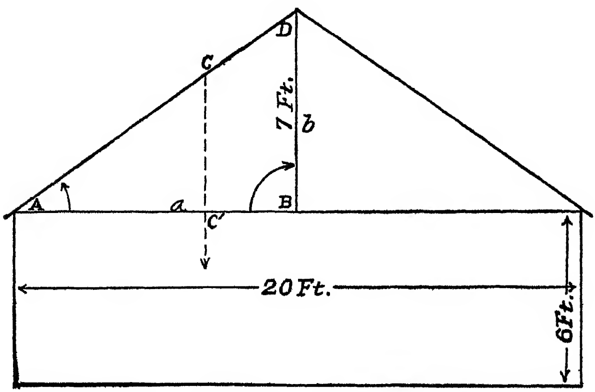


Fig. 23.—The pitch of the roof is measured at A.

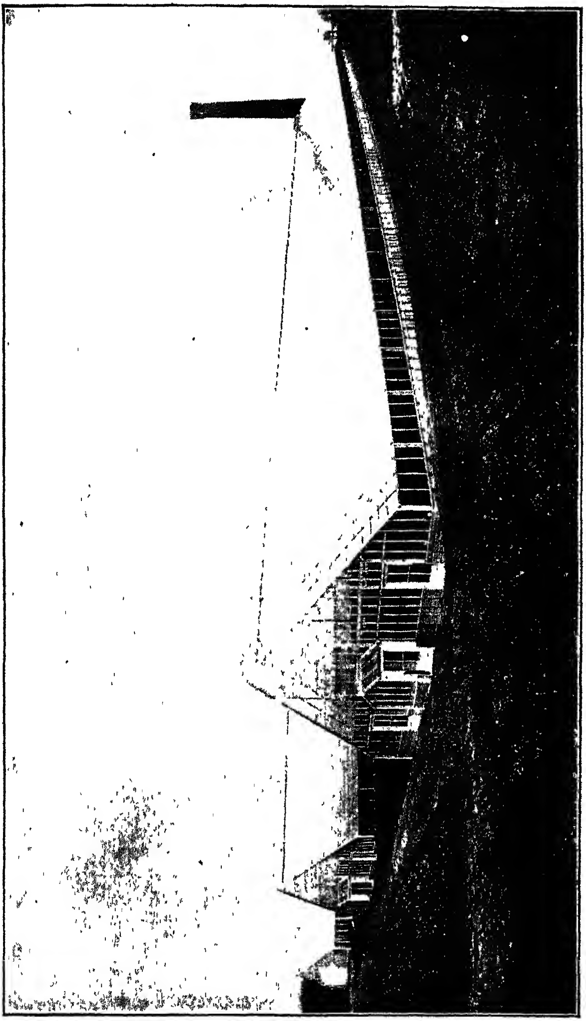


Fig. 24.—Commercial range showing wide, separate houses.

pass through it, but it also acts to some extent as a mirror, thus reflecting a part of the rays. The amount lost by reflection is proportional to the angle of incidence. Thus, if the sun's rays fall upon the roof at right angles, little or none is lost by reflection; but when they fall at a less

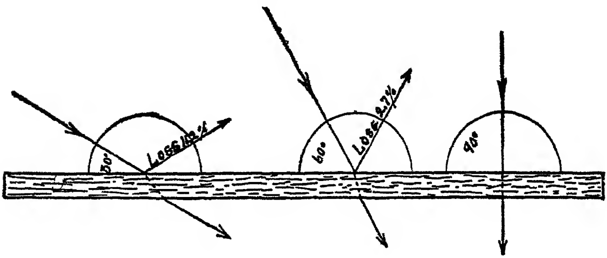


Fig. 25.—Diagram showing how heat and light are lost by reflection.

angle, the amount reflected increases as the angle of incidence increases. The amount of the sun's energy lost by reflection when the rays strike the roof at various angles is shown in the following table.

Table showing per cent. of sun's energy lost when the rays strike the glass at different angles

Angle of ray	Loss by reflection
60 degress	2.7 per cent.
50 "	3.4 " "
40 "	5.7 " "
30 "	11.2 " "
20 "	22.2 " "
15 "	30.0 " "
10 "	41.2 " "

It is apparent that the maximum amount of the sun's energy may be secured by a roof presenting to its rays an angle of 90 degrees. It is especially important that the energy of the sun be conserved during the short days of winter. At its lowest period the sun rises, in the latitude of New York, scarcely more than 25 degrees above the horizon at noon. In order for the roof to present an angle of 90 degrees to the sun's rays at this season, it would need to have a pitch of 65 degrees. Such a roof would be

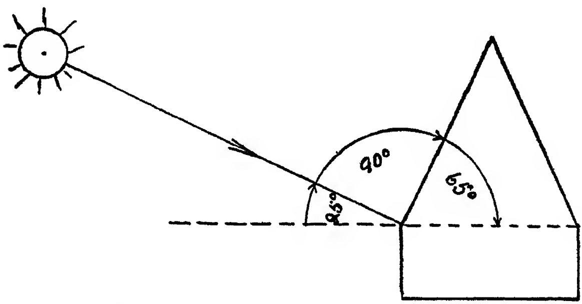


Fig. 26.—Diagram showing pitch of roof necessary to present an angle of 90 degrees to the sun's rays in winter.

(1) very expensive to build and maintain, (2) would present too large an amount of radiating surface for the space covered and (3) would be too high to be practical in houses more than 10 or 15 feet wide.

If, however, we reduce the pitch to 35 degrees, the sun's rays will strike the roof at an angle of about 55 degrees which, by reference to the table, will be seen to incur a loss by reflection of between 2 and 3 per cent. only. Roofs of this pitch are not difficult to build, and do not present so large a radiating surface for the area covered as do roofs having a pitch of 65 degrees. Roofs having a pitch of less than 26 degrees are seldom satisfactory because the snow does not clear from them well and they are likely to leak.

The water of condensation which forms on the inside of the roof is also likely to drip upon the plants when the pitch is less than about 26 degrees. When the pitch is greater, the water will usually follow down the glass to the edge of the house. In even-span houses (see Chapter IV) the pitch of the roof varies from 26 to 35 degrees, 26 and 32 being the most popular. In some specially constructed houses it is as great as 45 degrees. Most builders equip houses up to 25 feet in width with roofs having a pitch of 32 degrees, and above 25 feet with roofs having a pitch of 26 degrees.

Measuring the Pitch.—The degree of pitch of any even-span roof may be determined trigonometrically when the width of the house and

the height of the ridge is known or can be measured. If the house illustrated in Fig. 23 is 20 feet wide and the ridge is 7 feet above the eaves, the value of the angle, known as A, may be found by the following formula: Tang. $A = \frac{b}{a}$ equals Tang. $A = \frac{7}{10}$ equals Tang. $A = .700$ or $A = 35$ degrees.

Should the house be of uneven span it is only necessary to measure the distance corresponding to **a** (Fig. 23) and apply the same formula. When this is not convenient, a plumb bob may be dropped from any part of the roof, as at **c**, and the distance measured from the roof to the point c^1, where it cuts a horizontal line or straight edge from the point where the roof joins the wall. This distance may be substituted for **b** in the formula, and the distance from c^1 to the intersection of the roof and wall may be substituted for **a**. To avoid error the triangle thus formed should be as large as possible and care taken to see that the lines are perfectly vertical or horizontal, as the case may be. By referring to the following table the angles in degrees and minutes formed by roofs on houses of various widths and heights of ridge may be quickly found. The figures in the left-hand column correspond to half the width of even-

span houses or to the distance represented by **a** in the above formula.

Table showing angle formed by roofs on houses of different widths and heights of ridge

One half width in feet	Height of ridge in feet 4	5	6	7	8	9	10
	° ′	° ′	° ′	° ′	° ′	° ′	° ′
6	32 21	39 48	45	49 24	....	....	....
7	29 44	35 32	40 36	45	48 49	....	....
8	26 33	32	36 52	41 11	45	48 32	....
9	23 57	29 3	33 5	37 52	41 38	45	....
10	....	26 33	30 58	35	38 39	41 59	....
11	....	24 26	28 36	32 28	36 2	39 17	42 13
12	....	22 57	26 33	30 15	33 41	36 52	39 41
13	....	....	24 47	28 18	31 36	34 42	37 34
14	....	....	23 12	26 34	29 44	32 44	35 34
15	....	....	....	25	28 4	31 00	33 40
16	....	....	....	....	....	24 13	26 32

It is perhaps more often desired to find the length of rafter necessary to form a roof of given pitch on a house of given width, than to determine the pitch of a house already erected. This may also be solved trigonometrically. For example: Suppose it is desired to know the length of rafter necessary to form a roof with a pitch of 35 degrees on a house 20 feet wide. If the roof is to be of even span, as shown in Fig. 23, we will have a right angle triangle, A B D, the base of which is known to be half the width of the house, or 10 feet. If the angle A is to be 35 degrees then: Cosine $A = \frac{10}{X}$ equals $.81915 = \frac{10}{X}$. Transposing, $X = \frac{10}{.81915}$ or $X = 12.2$ feet.

This formula is also applicable to an uneven span roof provided the distance from the point directly underneath the ridge to either side of the house is known. For example: In a 20-foot three-quarter span house, the base corresponding to **a** of the triangle A B D in Fig. 23 is either two-thirds or one-third of 20 feet, according to which side of the roof we wish to measure.

In the following table will be found the lengths of rafters required to form roofs of various angles on houses of different widths. The figures in the left-hand column correspond to half the width of an even-span house or the horizontal distance from the eaves to a point directly underneath, where it is desired to place the ridge.

Table giving length of rafters necessary to form roofs of various angles on houses of different widths

One half width of house in feet	Pitch in degrees 26½°	30°	32°	34°	35°	40°	45°
	LENGTH OF RAFTERS IN FEET						
6	6.67	6.92	7.07	7.23	7.32	7.80	8.48
8	8.90	9.23	9.44	9.65	9.76	10.70	11.31
10	11.12	11.54	11.79	12.06	12.20	13.05	14.14
12	13.35	13.84	14.14	14.46	14.64	15.60	16.96
12½	13.90	14.43	17.73	15.09	15.25	16.33	17.67
15	16.80	17.32	17.68	18.09	18.30	19.57	21.21
20	22.44	23.08	23.58	24.12	24.40	26.10	28.28
25	27.80	28.86	35.46	30.18	30.50	32.66	35.34

CHAPTER IV

GREENHOUSE ARCHITECTURE

Architecturally, the different forms of greenhouses are named and recognized mainly by the style of roof.

Lean-to or Shed-roof Houses.—These are the simplest forms of greenhouses; likewise the least expensive and least satisfactory. There is little excuse for building separate houses of this type, but they may be made to serve a useful purpose when erected against the side of a building or against a steep side hill. They usually extend east and west, with the high wall to the north and the roof sloping toward the south. For commercial purposes they are of little value, as they admit light from only one side, and but little direct sunlight, except for a few hours in the middle of the day. They may be utilized for growing ferns and other plants requiring little direct sunlight, also for starting early plants, or as grape or peach houses, the vines or trees being trained against the north wall.

Lean-to houses not only have the advantage over other types in less first cost, but also in cost of maintenance. They have less glass surface in proportion to the area covered; hence there is less breakage, and for the same reason they radiate less heat. For amateur use, especially when they can be erected against the south side of the dwelling, they may be built and operated at small cost and will afford much pleasure.

Even-span or Span-roof Houses.—In these houses, as the name indicates, the sides of the roof are of equal length. They are the most popular form, fully 80 per cent. of all houses of recent construction being of this type. They are superior to the lean-to in that they admit light from two sides, and also because they may be run either north and south, or east and west, as may be desired. On this point, however, practical growers disagree, some preferring the east and west arrangement, others the north and south. Theoretically, the points in favor of and against each seem to about counterbalance. They are stated in the following paragraph.

The north and south arrangement permits direct sunlight to fall on both sides of the house for an approximately equal time during the day, thus giving all the plants in the house

an equal chance. It also permits the workroom to be placed on the north end, where it will not shade the house. The principal disadvantage is that during the middle of the day, when the sun's rays are most potent, they strike obliquely against the roof and much heat and light is lost by reflection. Moreover, a large part is cut off by the sash bars and rafters.

In the east and west arrangement, the direct sunlight enters from the south side only, and in the morning and afternoon strikes the roof obliquely. During the middle of the day, when it is most effective, it strikes almost at right angles, although it is not evenly distributed and the plants on the north side of the house receive much less than those on the south side. This would seem to be a serious fault, but in practice is less serious than in theory. Of 110 growers whom the author consulted on this point, 38 were in favor of the north and south arrangement, 42 were in favor of the east and west and 30 expressed the opinion that there is little or no difference.

Uneven Span Houses.—The uneven distribution of light in even-span houses running east and west early led to the experiment of cutting off the north one-fourth, so as to make an uneven or three-quarter span house. The follow-

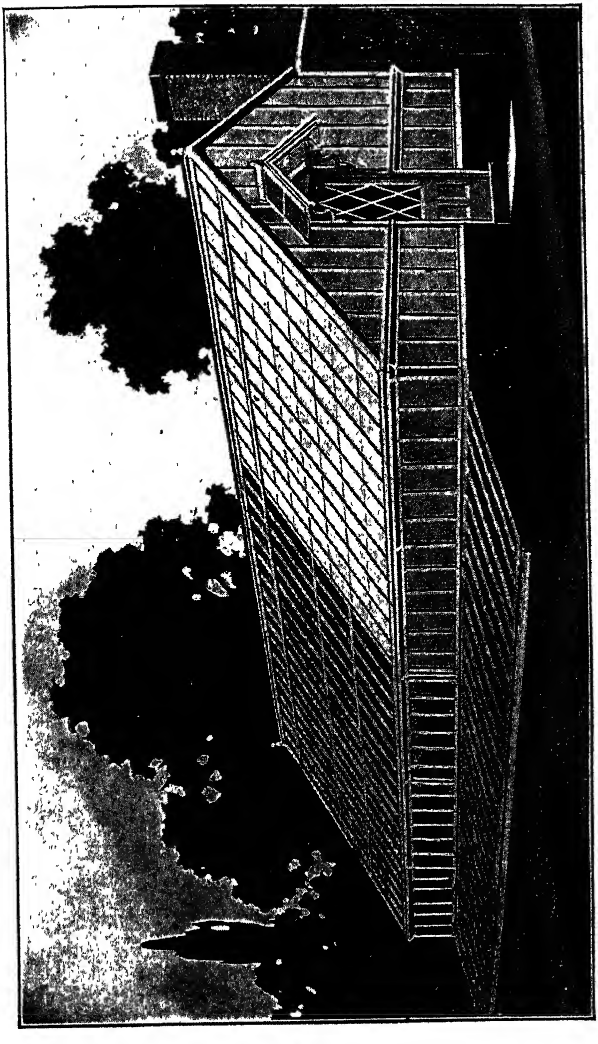


Fig. 27.—An uneven span house with a row of sash beds along the side.

ing advantages are claimed for these houses: (1) They secure a more even distribution of direct sunlight to all plants. (2) The north span admits indirect light which insures better results than may be secured from a lean-to house. (3) The heat is more evenly distributed than in a lean-to house. They are often used in growing roses and other plants requiring a maximum of light. The construction of uneven span houses has been varied from time to time, the general tendency being to lower the north wall to approximately the height of the south wall. This arrangement insures even better distribution of light and does away with the necessity of elevated benches.

Uneven span houses are sometimes used for growing lettuce and other vegetables directly on the ground instead of in benches, especially on sloping locations. Modern greenhouses are so much lighter than the older types that the advantages of the uneven span house in this connection are hardly worth considering. They are much less commonly built than formerly. Uneven span houses are sometimes constructed with the short span to the south with a pitch of 40 degrees or more. This brings the roof more nearly at right angles to the sun's rays, but has little or nothing to recommend it.

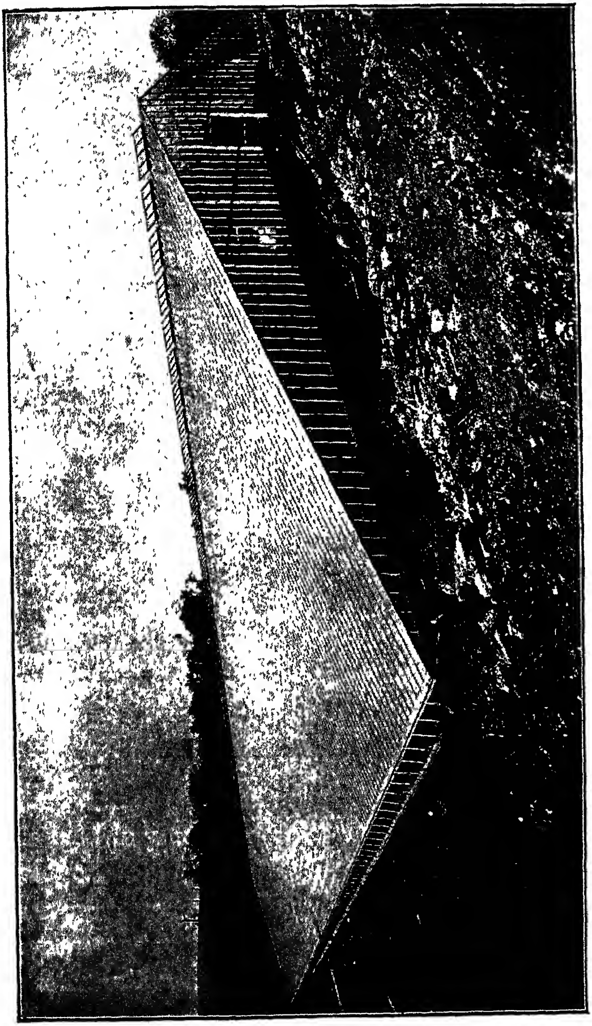


Fig. 28.—Uneven span side-hill vegetable house.

Ridge-and-Furrow Houses.—A ridge-and-furrow house is in reality simply two or more houses joined together. They may be even span or uneven span so long as the side walls are of equal height. The advantages of this form of construction may be mentioned as follows: (1)

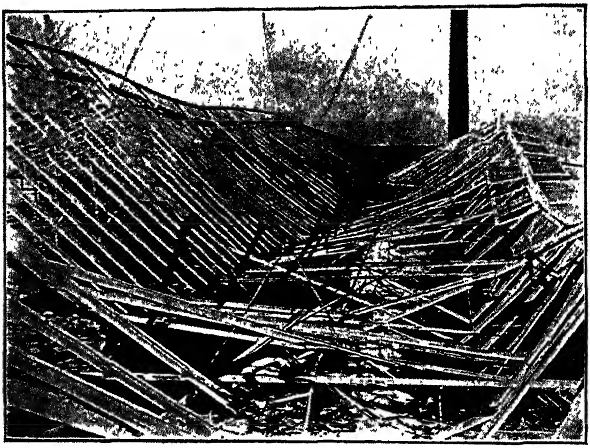


Fig. 29.—Ridge-and-furrow houses wrecked by a storm.

They are less expensive to build than separate houses of similar size, on account of the saving in side walls. (2) Not only is there a saving in the number of side walls, but the interior walls may be of cheap construction or may be left out entirely, the weight of the roof being supoprted by posts alone. (3) Considerable saving is

made in labor because easy passage may be had between houses. (4) They conserve ground space which is often a considerable item. (5) The houses in the center are protected from wind by those on either side and the radiation is thus reduced. (6) Because there is less exposed wall surface, and because the interior houses are protected, they require less fuel than do separate houses.

One of the chief objections to the ridge-and-furrow system of construction is the diffculty of removing snow from between the houses in regions subject to heavy snowfall. Other disadvantages are: (1) The center houses are shaded more or less, (2) side light and side ventilation can not be had, and (3) soil and other materials must be carried into the house from the end instead of being put in at side openings. The latter is a serious objection only when the houses are long and narrow.

The above remarks refer only to separate and connected houses of similar sizes. At the present time there is a difference of opinion as to the advantages of the single wide and high house over the small and lower houses connected in the ridge-and-furrow system. Contrary to the prevailing notion, the same amount of glass

is required by each system if the roofs are of the same slant or pitch. (Fig. 30).

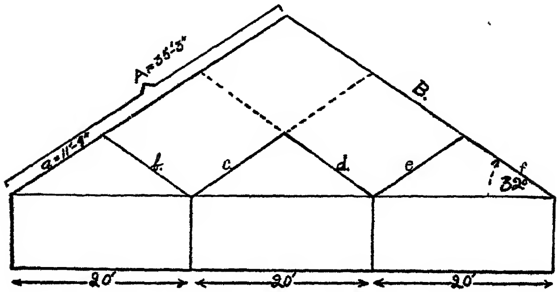


Fig. 30.—Diagram showing that the same amount of roof is required for several small, connected houses as for one large house covering the same area if the pitch is the same. a+b+c+d+e+f=A+B.

The following advantages are claimed for large, single houses: (1) They are more easily kept at an even temperature, (2) ventilation may be had without subjecting the plants to cold drafts, (3) they are lighter, (4) they are more easily cared for, (5) the light is more equally distributed over the whole house, (6) they quickly clear themselves of snow, (7) they contain a larger volume of air, and (8) they require fewer ventilators and less ventilating machinery.

On the other hand the following disadvantages are pointed out: (1) Their greater height

makes them a target for storms which in winter cause a greater radiation of heat, (2) they are less easily re-painted and re-glazed, and (3) the first cost is greater.

Notwithstanding these objections, however, separate houses of moderate size (40 to 60 feet in width) seem destined to become more and more popular.

Hip-Roof Houses.—Hip-roof or gambrel-roof houses are modeled somewhat after the modern farm barn; that is, the lower part of the roof is at a steeper angle than is the upper part. As usually constructed the lower half has a pitch of about 45 degrees and the upper half about 26 degrees. It is claimed for houses of this type that they utilize to better advantage the heat and light of the sun during early winter, when the sun is at its lowest, as the steep part of the roof is more nearly at a right angle to the sun's rays than is the case in conventional even-span houses.

Curved-roof Houses.—Curved or curvilinear roofs are now seldom seen, except on conservatories and show houses. Their chief use is for ornamental effect. They originated in an attempt to so arrange the glass as to more perfectly intercept the direct rays of the sun, but in practice they have proved little, if any, superior

to the straight roof, and the expense is considerably greater. They have never come into general use in a commercial way. Curved-roof houses are made to use either curved or straight glass.

Side-hill Houses.—Mention has already been made of one of the forms of this type of

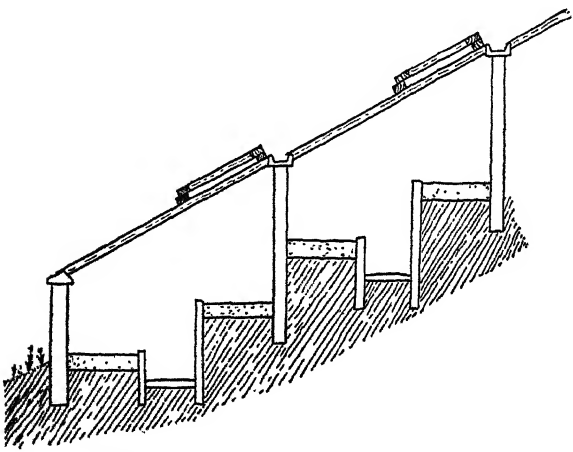


Fig. 31—Diagram of a side-hill range.

house. Sometimes a modification of the ridge-and-furrow house is utilized for side-hill construction. Side-hill houses are not recommended when well drained, level land may be had, because of the disadvantage of working at different levels.

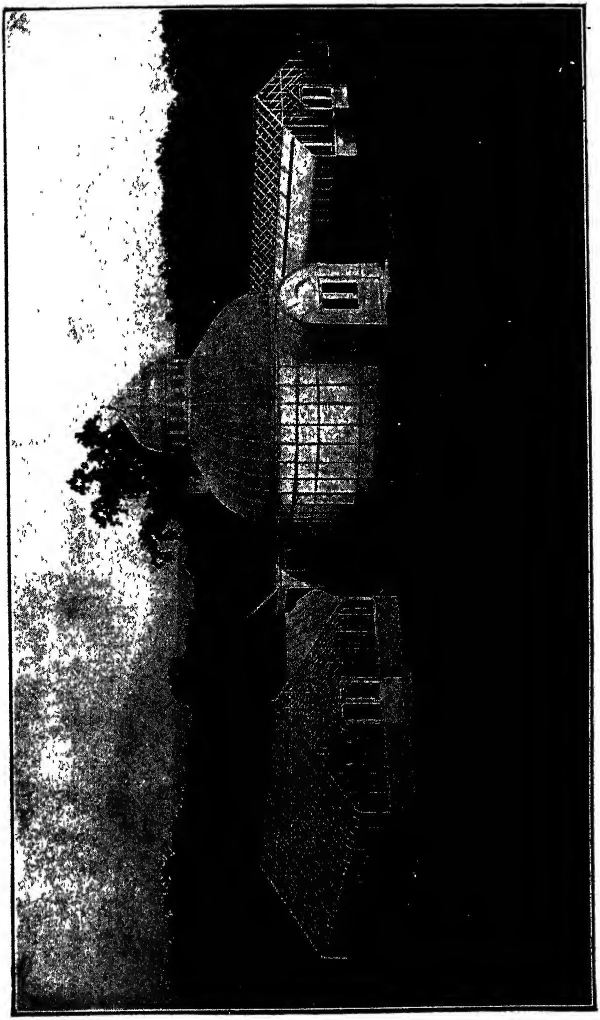


Fig. 32.—Curved-eave and circular types of construction.

Curved-eave Houses.—The shade caused by eave plates and gutters, the difficulty of keeping them in repair and their interference with the clearing from the roof of ice and snow in winter, has led to the adoption of the curved-eave construction. For small and medium-sized houses the increase in light is very noticeable. In larger houses it is not so apparent. The expense for glass is somewhat greater on account of the curved panes required.

Circular Houses.—These belong in a class with the round barn and octagonal house—excellent in theory but impractical in use. Their first cost and the expense in maintenance places them without the range of economy as commercial houses. As ornamental houses in parks and private estates they have a place.

CHAPTER V

STRUCTURAL MATERIAL

Practically all the material, whether it be wood or metal, which goes into the construction of a modern greenhouse, is milled or shaped at the factory. It will almost never pay the prospective builder to attempt to use material made by any but specialists in this line of work. There are several such firms in this country. Greenhouse construction, then, so far as the individual builder is concerned, becomes simply a matter of choosing the kind of material he desires to use; ordering it from a responsible manufacturer and assembling it or placing it in its proper position. Most greenhouse construction firms have certain standard or stock houses which they ship complete, even including nails, paint and putty if wanted, at a definite stated price; and they will erect them if it is desired. They will also design and build a house or range of houses to suit any given condition.

On the other hand, there is now such a variety of structural material to be had that it

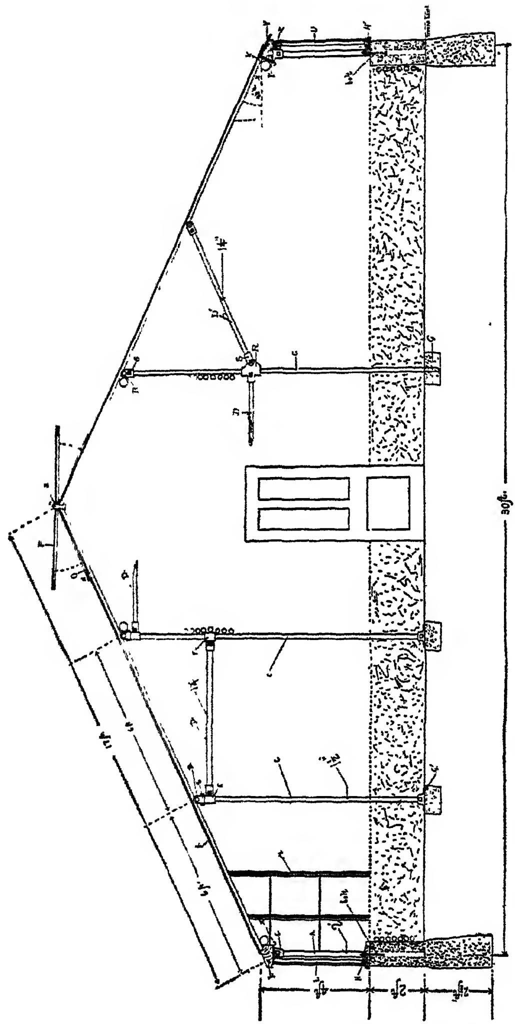


Fig. 33.—Two methods of framing a semi-iron pipe-frame greenhouse and the principal members used in greenhouse construction. A, side post; B, purlin; C, purlin post; E, F, G, R, and S, malleable iron fittings; H, glazing sill; H, sash sill; I, and Y, eave plates; J, ridge; K, sash bar; N, ventilating header; O, ventilator weather strip; P, ventilator; T, drip gutter; U, side ventilating sash; V, sash bar attachment for metal eave plate; Z, sash header.

is quite possible, and very often desirable, for the buyer to design a house according to his own ideas or to fit his own special needs or location; select and purchase the materials and erect it with his own help to suit his special requirements.

In order to do this it is necessary to know the names and uses of the various members which go to make up the house. The principal ones are shown in Fig. 33 and are described in the following paragraphs.

Glazing-sill or Sash-sill.—This sill is bolted to the top of the wall, usually by bolts set into

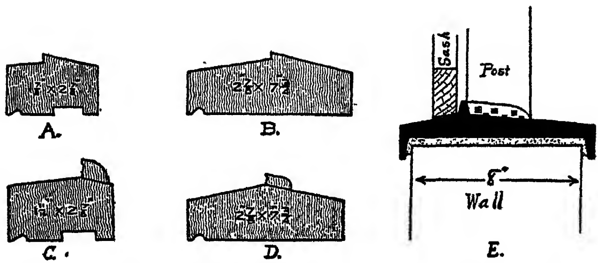


Fig. 34.—Types of sills. A, B, C, and D are wood sills; E is cast-iron.

the concrete, heads down, when the wall is built. It is known as a sash-sill when the house is equipped with ventilating sash along the side walls which close down against it; or as a glazing-sill when no side ventilating sash are used

and the glass is puttied directly against it. Sills are used at the ends as well as at the sides of the house. They are of various sizes and forms, and may be of either wood or iron. The small sills are now quite popular. Grooves on the under side of the wood sills prevent the water from running back between the sill and the wall which would thus cause decay.

Eave Plate.—This plate rests upon the side posts and forms the support for the roof members. It may be of either wood or iron.

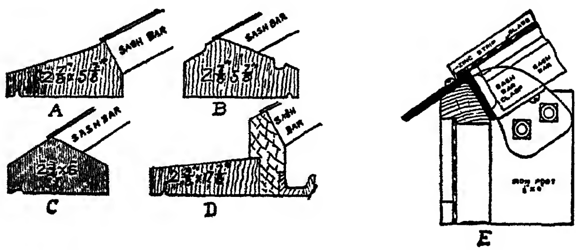


Fig. 35.—Types of eave plates. A, B, C, and D are wood; E is a metal plate.

Gutter.—When it is desired to collect the water from the roof, or when houses are connected in the ridge-and-furrow system, it is necessary to use a gutter instead of an eave plate. Metal gutters are rapidly displacing the old-fashioned wood gutters as they last longer,

and because they need not be so large and hence cast less shade.

When gutters are used, they have a fall of at least 4 inches for each 100 feet in length. This is accomplished by gradually shortening the

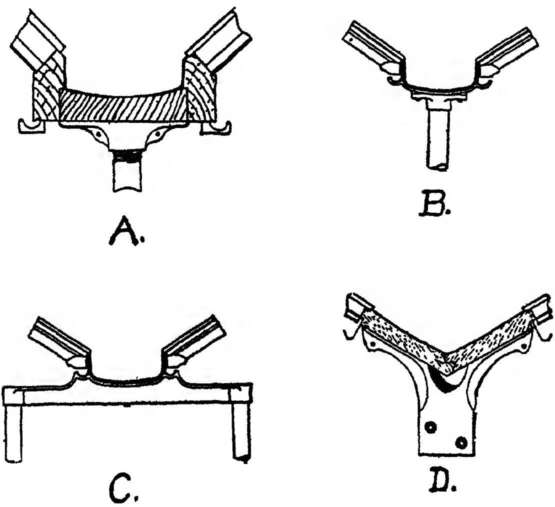


Fig. 36.—Types of gutters. A, and D are wood; B, and C are metal. C is supported by two rows of posts to allow for a walk directly underneath.

posts toward one end of the house. In other words, the side walls are higher on one end of the house than they are on the other. On very long houses the walls are sometimes so constructed that the gutter slopes from the ends

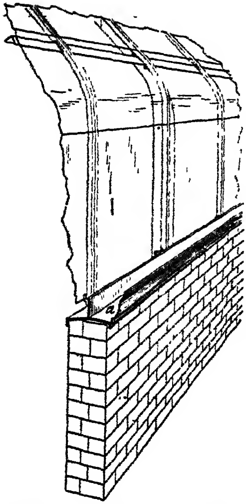


Fig. 37.—Type of gutter (a) used on curved-eave houses.

each way toward the center and the water is carried away at that point. Detached houses are less commonly fitted with gutters than formerly, on account of their interference with the clearing of snow. A special form of gutter is used on curved-eave houses.

Glazing Bars.—These are bars which are spaced along the sides and ends of the house to which the glass is fastened. They are much the same as sash bars, which will be described later, except that they are usually somewhat smaller and are not provided with grooves to conduct the drip. Corner bars serve the same purpose as glazing bars, except that they are so milled that they will take the glass from both sides and the ends

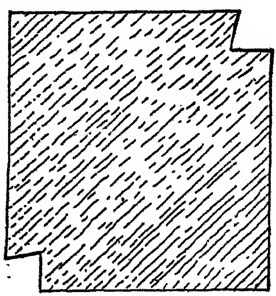


Fig. 38.—Cross section of corner bar

of the house. One is used at each corner.

Side Posts.—These posts bear the weight and side strain of the roof. They may be of wood, gaspipe, or structural iron or steel. Their size will depend on the height of the wall and the width and construction of the house. Wood posts 4 x 4 inches, 2 or 2½-inch gaspipe, or ½ x 3-inch structural iron or steel are usually considered amply strong for most houses. The gaspipe and steel posts are usually set in concrete and masonry. It is best to set the wood posts in the same manner. Occasionally the structural steel posts are bolted to iron sills which cap a concrete or masonry wall.

Sash Bars.—The sash bars are among the most important of all the members which go to make up a greenhouse. They must be strong enough to carry the weight of the glass, yet be of such form and size as to cast the least possible shade. They are of various forms and sizes. Bars made entirely of metal are seldom satisfactory for the following reasons: (1) They are likely to expand and contract considerably with changes in temperature, thus loosening and often breaking the glass. (2) The extreme cold to which they are subjected on the outside, as compared with the warm temperature on the inside of the house, has a tend-

ency to cause them to warp and thus break the glass or cause it to fit poorly. (3) As all metals are ready conductors of heat, much is lost by radiation when they are used. (4) In cold

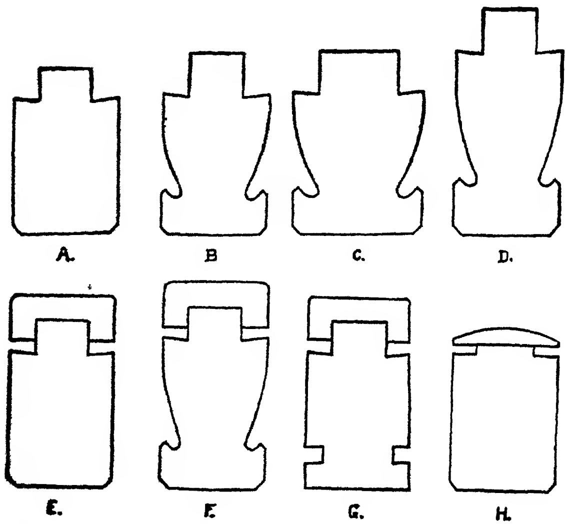


Fig. 39.—Types of wood sash-bars. E, F, and H are used for butted glazing; G is used for double glazing.

weather they become so cold as to cause the moisture in the air inside the house to condense rapidly on them, which results in a large amount of drip. Various types of bars have been invented in an attempt to overcome these difficulties.

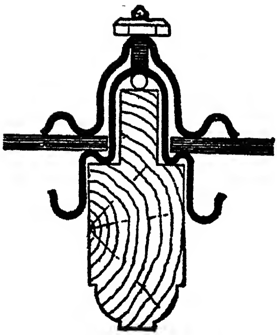


Fig. 40.—Two types of patented metal sash-bars.

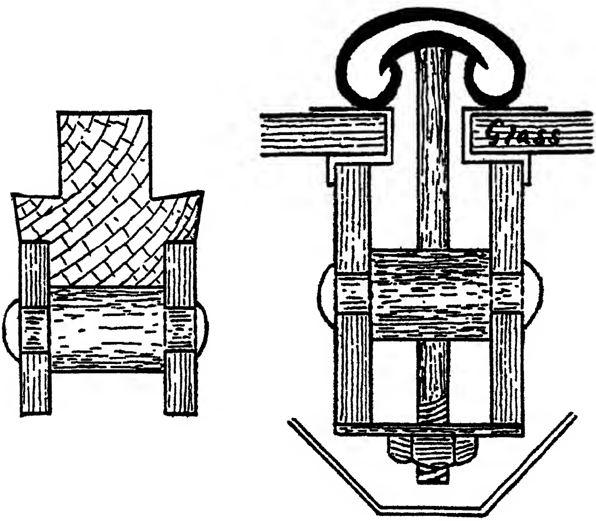


Fig. 41.—King "channel bars."

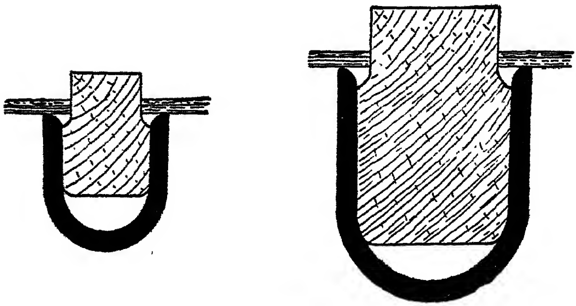


Fig. 42.—"U-Bar" type of sash-bar.

Wood sash bars are not good conductors of heat and condense but little moisture, but moisture from the glass finds its way to the sash bars, so that they are usually made with a groove or furrow on each side, which conducts the moisture down to the eaves. The most common size of wood sash bars is 1⅜ x 2½ inches. Larger bars are used for special purposes.

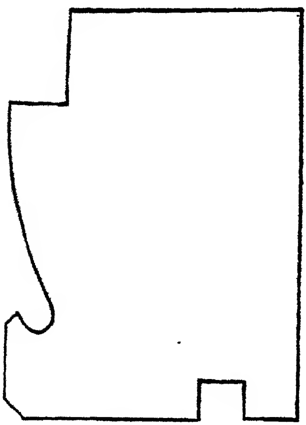


Fig. 43.—Gable rafter.

Gable Bars or Gable Rafters.—Gable rafters are used at the ends of the roof and are

made so as to receive both the glass of the roof and that of the end of the house. They should be large and strong enough to give rigidity to the gable.

Drip Gutter.—The purpose of the drip gutter is to carry away the water formed by condensation inside the house, which is conveyed to it by the sash bars. The pipes leading from it should empty into a cistern or sewer connection inside the house, or be carried out below the frost line. This is necessary to prevent freezing, as the greatest drip is in the coldest weather. In some forms of construction where pipe side posts are used, they are utilized as conductors of the drip water, but the saving thus accomplished is usually more than counterbalanced by the early rusting out

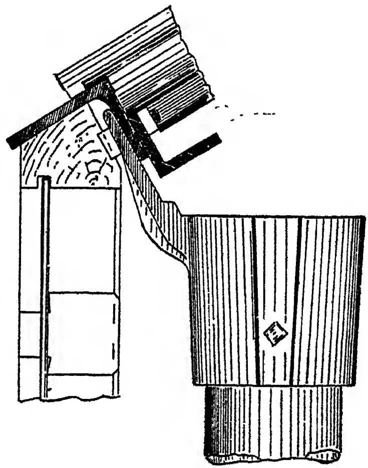


Fig. 44.—Combination eave plate and gutter.

of the posts. Gutters are made of wood, zinc, tin and galvanized iron.

Purlins.—Since sash bars must be small to minimize the amount of shade, it is evident that on wide houses they cannot carry the weight of the glass without support. This is accomplished

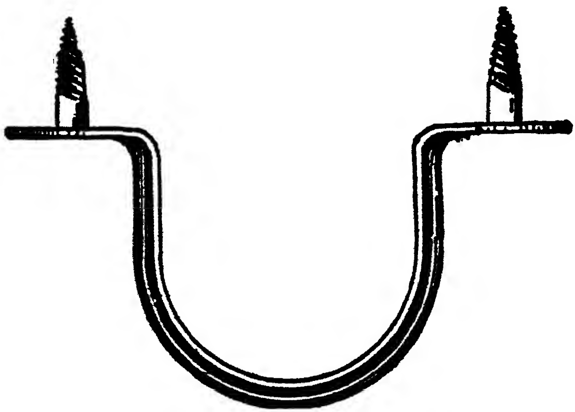


Fig. 45.—Pipe-strap for fastening sash-bars to purlins.

by means of purlins. They run lengthwise of the house, and are themselves supported by purlin posts, by purlin braces, by rafters or by some form of truss work to be described later.

When ordinary wood sash bars are used with glass 16 inches wide, the maximum distance for safety between purlins is not more than 7 feet. For example: If the sash bars are more than 7

feet long, one purlin should be used. If they are more than 14 feet long, two purlins should be used, and so on. This distance decreases as the size of the glass increases since there are fewer bars to sustain the same weight.

Purlins may be of wood, gaspipe or angle iron. Wood purlins, because of their size (1⅜ x 3 inches), cast so much shade that they are now little used. Purlins of 1¼-inch gaspipe are very satisfactory. They are fastened to each sash bar, and are supported by posts or braces every 8 feet along their length. A very satisfactory means of fastening them to the sash bars is by means of a U-shaped pipe-strap. This is placed under the purlin and fastened to the sash bars by means of screws.

Ridge.—The ridge furnishes a means of fastening the upper ends of the sash bars and also serves as a support for the ventilators. It is milled from a 2 x 4, or a 2 x 6-inch timber, the size depending on the width of the house. The form varies according to the method of attaching the ventilators. (See Chapter VIII).

Ventilators.—These are fully discussed in Chapter VIII.

Ventilator Header.—This is a member upon which the lower side of the ventilator rests. It is cut and grooved at the factory so as to fit

over the sash bars and to receive the edge of the glass of the roof in its lower side.

Sash Hanging Rail.—When side ventilating sash are used a special piece is sometimes placed immediately under the eave plate or gutter, to which the sash are hinged. This is known as a sash hanging rail. Sometimes the sash are hinged directly to the plate or gutter.

Weather Strip.—Because of their construction and the method of hanging, the roof ventilating sash do not fit down tightly upon the sash bars but leave wedge-shaped openings. These are closed by pieces known as weather strips.

Rafters.—Their use is now confined almost wholly to all-metal frame houses which are discussed in Chapter VI.

KINDS OF WOOD

Three kinds of wood are now being used in greenhouse construction: Cypress, cedar and California redwood. Of these the first two are preferred. There is little difference in the durability of cypress and cedar. If well framed, and if thoroughly painted when erected and at least once in two years thereafter, either will last a lifetime. Also see page 83.

Pecky cypress is the heartwood from old trees. It is full of holes or "pecks" and is often too "shaky" for sash bars and other small members, but it is one of the most durable woods

Fig. 46.—"Pecky" cypress.

known. It is used chiefly for benches, and in other places where ordinary lumber decays rapidly and where great strength is not needed.

FRAMING

The woodwork of a greenhouse always begins to decay at the joints. For this reason particular attention is paid to the framing. All joints are made to fit closely, and before putting together each piece should be primed with a thin coat of lead paint. The joints are then given a heavy coating of thick white lead and put together while the paint is still green.

In buying greenhouse material it is always well to buy all the woodwork from one firm and to give the concern a careful description of the

house, together with a drawing showing the width, height and length of the house, the pitch of the roof, size of glass to be used, etc. The firm will then send the woodwork (if it is so directed) cut so that it may be fitted together

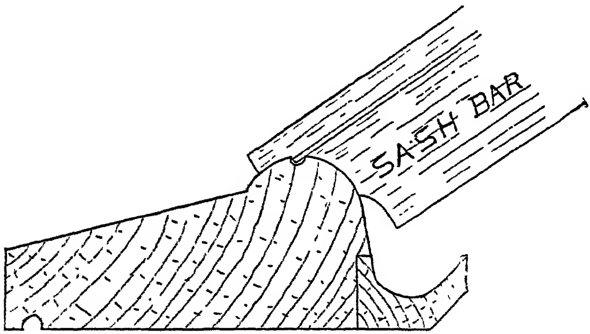


Fig. 47.—The concentric system of construction.

with but little trouble. It should be specified, however, that it be well seasoned and not warped. Warped millwork, especially sash bars and glazing bars, are exceedingly difficult to put in proper position.

Some factories now build their eave plates and sash bars on the concentric principle, which does away with the necessity of cutting the ends of sash bars differently for roofs of different angles.

Treatment of Wood to Resist Decay.—Cypress and cedar are considered the best woods for greenhouses and sashbeds because of their resistance to decay. Other woods may be chemically treated so that they are almost equally resistant.

Unfortunately most methods of treatment require either heat or pressure or both, the equipment for which is rather expensive. Generally speaking it is cheaper to purchase treated lumber than to attempt to treat it under home conditions. On the other hand wood for sashbed frames and for posts and outside woodwork for wood-frame greenhouses may sometimes be purchased locally at a price which may justify some kind of home treatment.

Creosote has long been used as a wood preservative. There is a prevailing opinion among greenhouse operators that the fumes from creosote treated lumber are injurious to plants. While there seems to be little scientific data to bear out this opinion it is true that the odor is unpleasant and that it is sometimes transferred to cut flowers and vegetables. Some growers contend that creosoted lumber does not paint well—that it stains the paint. Creosote may be used for posts, since only the part to be under

ground is treated, and for the boards used for the outside wall.

Treatment is given by placing the lumber in a metal tank, covering it with the liquid and applying heat. Posts may be stood upright in the tank, only the portion to be placed under ground being submerged in the liquid. Heat expells the air from the pores of the wood. On cooling a partial vacuum is formed into which the creosote flows thus impregnating the wood.

Custom plants for the treatment of fence posts have been established in many localities and where available may be utilized for treating posts for any purpose. It is also possible to purchase creosote treated posts.

Another method known as the Osmose Process is an easier method but is open to the limitation that it can be used only with green or freshly cut lumber. The preparation used is a commercial product. Is painted on the wood and penetrates by osmosis hence its name.

Most commercially treated lumber is treated with one or more chemicals which are toxic to rot producing organisms and rely on pressure to force them into the wood structure. Among the chemicals so used are dinitrophenol, sodium fluoride, bichromate of potash, and chromated zinc chloride. There are several commercial

preparations variously recommended as wood preservatives.

Those contemplating the treatment of wood to resist decay are advised to contact their State Agricultural Experiment Station.

CHAPTER VI

FRAMEWORK—METHOD OF ERECTING

The two cardinal virtues of a good greenhouse framework are these: It must be strong and light, and it must cast but little shade. The greatest advance in greenhouse construction has been in the framework. The old houses with their high, solid walls and heavy woodwork are dingy and dark, when compared with the modern house, 90 per cent. of which is glass, with little or no solid wall above ground. The framework of these houses casts but a fraction of the shadow produced by the old-style frame, yet it is so perfectly rigid against storms and snow that the large panes of glass are seldom broken or even loosened in their setting.

Three general classes of framework are used: (1) Wood frame, in which all members, including the posts, are of wood; (2) semi-iron frame, in which the posts, purlins and purlin posts are of pipe or structural iron, and (3) all-iron or all-steel frame. In wood and semi-iron construction, rafters are seldom used, the sash

bars performing this function as well as their own. These forms have the advantage of being somewhat cheaper than the all-metal frame construction, and have the additional advantage that the material may be cut and fitted on the job by any experienced workman.

Wood frame houses cast more shade than semi-iron, and are less durable, especially the posts. Semi-iron houses are durable, and for houses of medium width, are very satisfactory. Probably more houses of this type have been built during the past twenty-five years than of all others, though the all-metal frame house is gaining in favor.

The all-metal frames are cut and fitted at the factory and are then shipped, knocked down, to the place of erection. Most styles of all-metal frames have rafters, which are bolted to the side posts by means of gusset plates to form bents. The bents are then placed in position and secured by stays and purlins. Upon this framework are then bolted the wood sash bars and glazing bars. Metal sash bars, as before mentioned, seldom prove satisfactory. The framework of such houses is practically indestructible, and when the woodwork decays it can be replaced upon the old framework.

Usually the weakest part of a greenhouse is

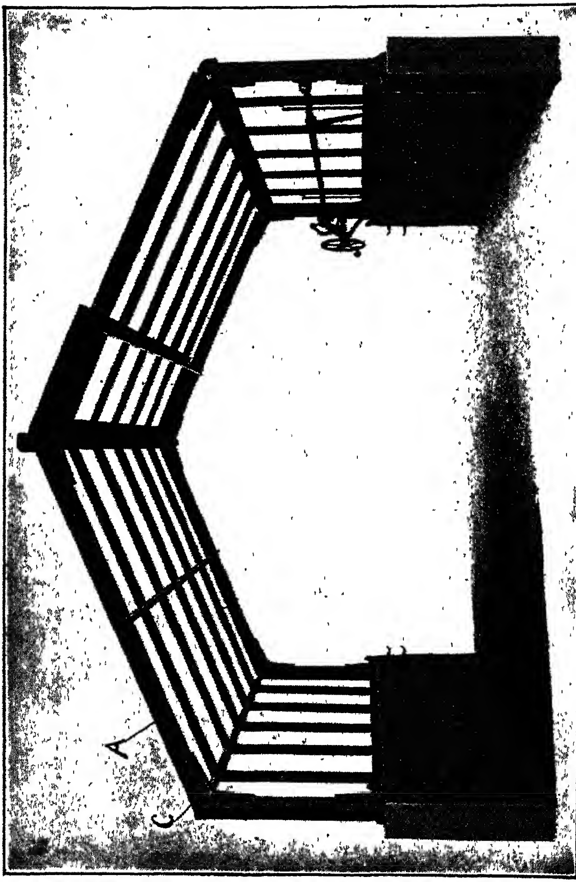


Fig. 48.—A type of all-metal, flat-rafter construction. A, rafter; C, gusset plate.

the gable. It should be well framed and securely tied to the purlins and other parts of the framework.

METHODS OF ERECTION

Foundation and Walls.—In the old-style high, solid wall greenhouse, the wall was a source of much perplexity, especially the high north wall of the uneven span house. In modern houses, however, the solid wall is seldom higher than the top of the benches, when benches are used, or only a few inches above the surface when plants are grown on the ground. The remaining part of the sidewall is constructed of posts and glass, thus giving more light. The chief difficulty with the high, solid wall was that the extremes of temperature between the outside and inside in cold weather caused them to disintegrate rapidly. This was particularly true with masonry walls.

Modern greenhouse walls, for commercial houses, are almost always of concrete and, being low, give little trouble. Concrete blocks and hollow building tile are much used. The chief requisite is that the foundation shall reach below the frost line. The common practice is to dig a trench 12 or 15 inches wide and 3 feet deep and fill with coarse concrete to within a

few inches of the surface. A form is then built of lumber to the height required and filled with concrete. When the concrete has "set," the form is taken away and the sides of the wall plastered with a cement mortar. In wet, springy soil it is often desirable to lay a row of drain tile along the outside of the wall at the bottom of the trench, to carry off the water.

Concrete walls are usually much more satisfactory than either brick or stone. They should be from 8 to 12 inches thick, according to their height and the side strain to which they are subjected. Usually 8 inches is sufficient. In wet soils when the boiler is placed below the surface, it may be necessary to waterproof the walls. For data on concrete construction see Chapter XV.

Wood Frame Houses.—These are quite satisfactory when a cheap house is wanted for a comparatively few years. The side posts, which may be of cedar or cypress, and 3 x 4 inches in size, are placed 8 feet apart in holes 3 feet deep, and extend to the height decided upon for the side walls. They are then placed in alignment and the holes poured full of thin concrete which soon hardens. The end posts are similarly placed, except that they extend only

to the height of the boarded-up portion of the wall.

The next step is to place the center posts, which are usually 3 x 3 or 4 x 4 inches in size. The height of the ridge having been determined

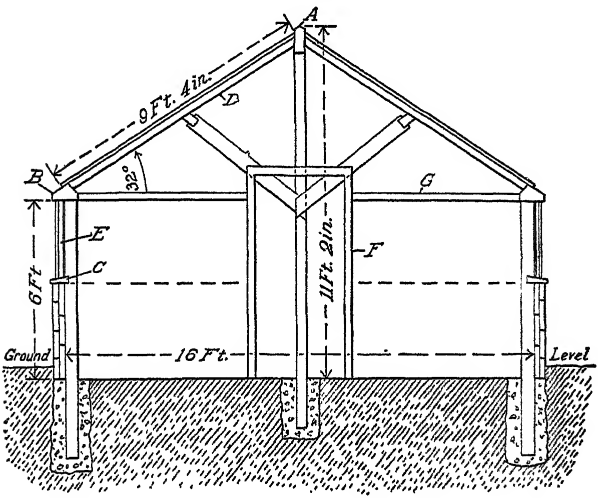


Fig. 49.—Plan for an all-wood frame greenhouse.

(see Chapter III) these posts are cut long enough to allow the lower end to be set in the ground about 2 feet. They are then put in alignment and embedded in concrete the same as the side posts. The ridge is then put in place on top of these center posts, and the eave plate

on top of the side posts, all joints being set in thick white lead paint.

The sash bars on a house over 12 feet in width must be supported with purlins, but it is not necessary to support them with two extra rows of posts. A perfectly safe and much more convenient way is to support them with arms or braces from the center posts. This saves valuable ground space, and the arms serve to stiffen the center posts as well. The length and position of these arms may be determined by placing a straight edge from ridge to eave plate in just the position the sash bars will occupy, and nailing the arms fast, first allowing for the thickness of the purlin. A good mechanic would have determined this before the posts were set, and have nailed the arms in place before raising them. The amateur, however, will find it best to put them in place after the posts are up, or at least to put up a trial post and then make the others after it as a pattern.

The next step is to nail on the purlin, and then it is ready for the sash bars, which are spaced carefully so that the distance from rabbet to rabbet is about one-eighth-inch greater than the width of the glass. This can best be accomplished by using a board about one-eighth-inch wider than the glass, and nailing the bars

so that the rabbets fit snugly against it along their whole length. The board can then be removed and used to space the next, and so on.

The side and end posts are next boarded up to the required height, using two layers of matched lumber with paper or insulating board between. Glazing bars may now be fitted along the sides between the eave plate and the glazing sill, and between the glazing sill and the gable rafters. Corner bars are placed at each corner.

It will also be necessary to make a frame for the door at one end, and to reinforce the gable glazing bars with 2 x 4-inch scantling. The house is then ready for glazing, instructions for which will be found in Chapter VII.

If cypress or cedar lumber is used throughout, and if kept carefully painted, a house like the above should last for fifteen or twenty years. The most vulnerable parts are the posts, especially the portion where they enter the cement.* While these houses do not admit as much light as either a semi-iron or an all-iron frame they will give excellent service. A poorly built all-wood frame house is a constant expense for maintenance.

Semi-iron Frame Houses.—Two methods of framing a semi-iron frame house are shown

* See Chapter IV for treatment of posts to resist decay.

in Fig. 33. The method shown on the left requires twice as many purlin posts as the one on the right. In each case gaspipe is used. The work of erecting differs but little from that described for wood frame houses, except that pipe working tools are required, and a little more skill is necessary. An endless variety of fittings may be had for this style of framing, which makes the joining of the frame work comparatively easy.

If it can be procured, genuine wrought-iron pipe is best used instead of the steel pipe now commonly sold. Steel pipe rusts out much more

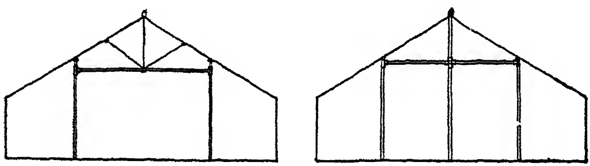


Fig. 50.—Two methods of framing a semi-iron house. For others, see Fig. 33.

quickly. In this style of house the wall is usually of concrete and may be only a few inches above the surface of the ground, or any height desired. The side posts which are usually of 2-inch pipe are put in position and stayed before the concrete is poured in, so that when the wall has set they are perfectly in line and

rigid. Adjustable brackets which fit on the top of the posts, and to which the eave plate or gutter is attached, make possible the correction of trifling variations in height.

Bolts are set, heads down, in the top of the wall while it is soft, and project upward. These are used for fastening down the sill, which is bored to fit over the posts and bolts and is secured with nuts. No posts are set in the end walls, but the bolts are set the same as in the side walls and are used for the same purpose. In some cases the posts are set in the ground and the side walls are constructed of two layers of matched lumber.

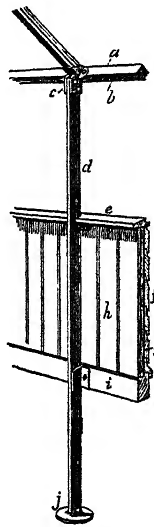


Fig. 51.—Structural steel post with board wall.

The purlin posts and other supports are put in position much the same as in the wood frame house, except that instead of being embedded in concrete, they are sometimes provided with foot pieces and rest on small concrete piers. Split malleable iron castings may be had in almost every conceivable form for joining the frame together. These are fastened by bolts and set screws, so that it is not

necessary to thread the pipe. The sash bars are fastened to the pipe purlins by means of U-shaped clips or pipe-straps, which are secured to the bars by means of screws. Purlins are usually made of one and a quarter-inch pipe and should be supported by posts every 8 feet. Purlin posts are usually of one and a half-inch pipe and braces of one and a quarter-inch pipe.

A well-built house of this type, if well cared for, should last a lifetime.

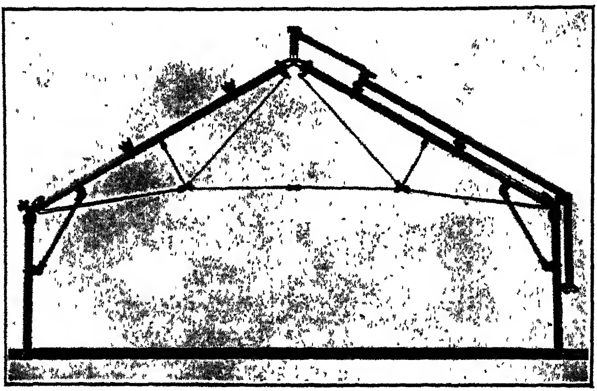


Fig. 52.—Section of truss-frame greenhouse. The frame is made of gaspipe.

Semi-iron frames are also made from structural iron instead of pipe. They are just as satisfactory, but are not so easily worked, and are usually cut and fitted at the factory.

All-metal Frame Houses.—There are three types of all-metal framework: (1) Those in which the roof is supported by interior posts, much the same as in the wood or semi-iron houses. (2) Those in which the roof is supported by a truss work, thus doing away with all interior posts (sometimes known as truss-frame). (3) A combination of the above forms (known as a combination truss-frame) is used in houses so wide as to make the truss-frame impractical. This is commonly used in houses over 40 feet in width.

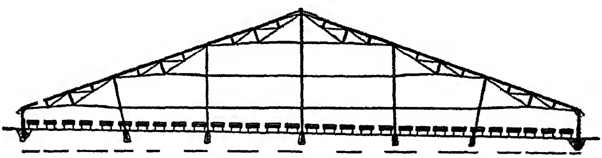


Fig. 53.—Section of combination truss-frame greenhouse, 172 feet wide.

As has already been mentioned, all-metal frame houses usually have wood sash bars and glazing bars, but they are not considered as parts of the framework. In these houses the completed framework is entirely of metal, the wooden members being fastened to the frame with bolts or screws and serving only to hold the glass in place.

In many all-metal frame houses, especially when the roof is supported by inside posts, it is common to bolt an iron or steel sill to the wall and then bolt the side posts to this sill.

A method of erecting a modern combination-truss frame house, 73 feet wide and nearly 30 feet high, to the ridge, is shown in Fig. 54. This work was done entirely by the owners and their ordinary help, without any expert supervision and at a material saving in cost.

The method was comparatively simple. The material was first carefully distributed on the site selected, and a trench dug for the foundation. The gable trusses were then bolted together, while another gang of men began setting and guying the side posts. The trench was then filled with concrete, making the side posts rigid. Next the interior posts were put in place.

The first step in putting up the rafters was to fasten the lower ends to the tops of the side posts loosely, so that they would move easily, and then raise the other end into place by means of a pair of "shears," made of two pieces of 2 x 4-inch scantling. When these had been securely bolted in place, the gable truss, which had been previously assembled, was swung into place by means of a block and tackle, working

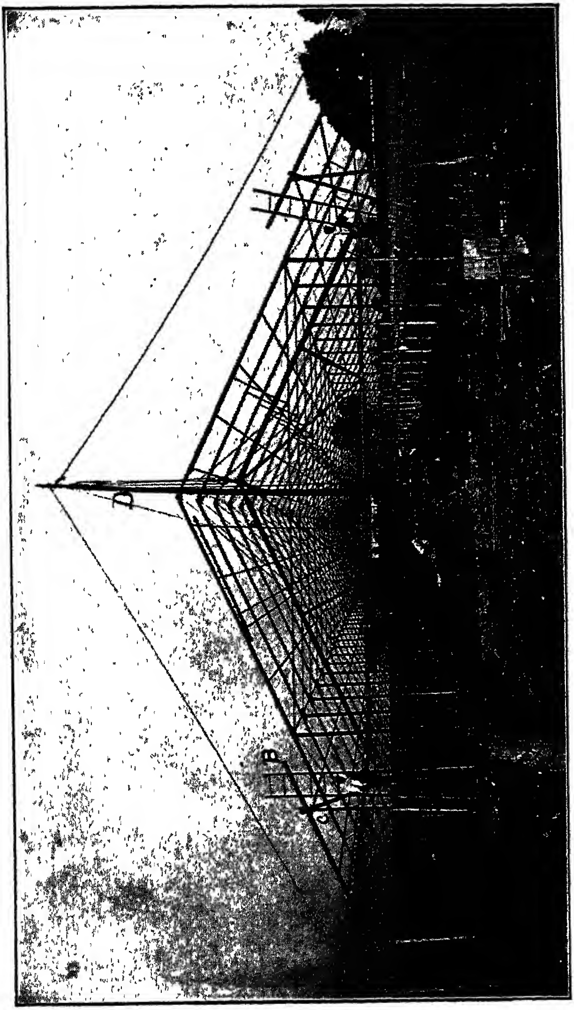


Fig. 54.—Method of erecting a large combination truss-frame house.

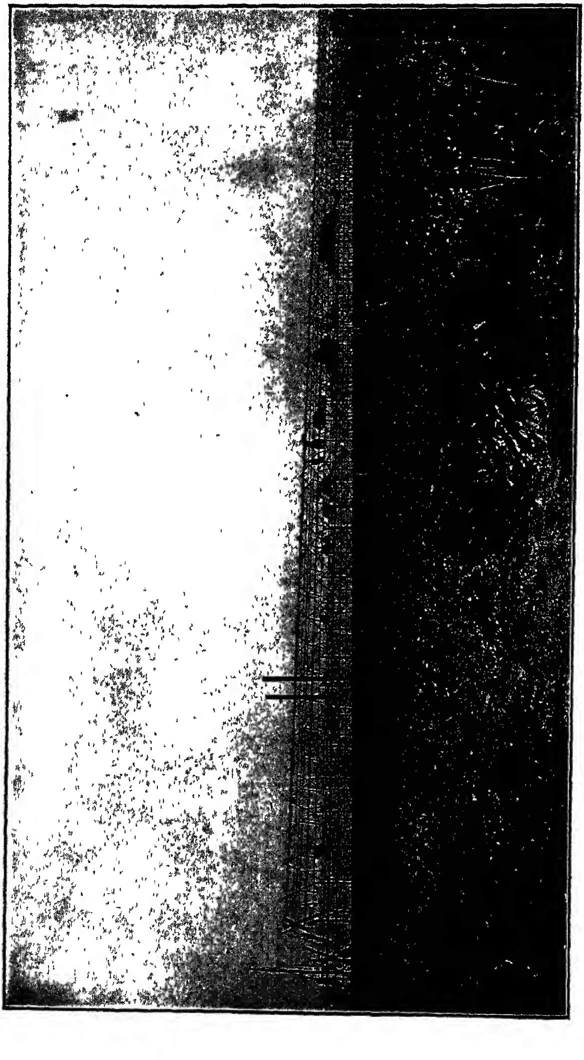


Fig. 55.—Side view of house shown in Fig. 54.

from a boom. All that remained was to insert and tighten the bolts, put the purlins in place and move on to the next bent. The author was told by the owners of this house that it was erected with greater ease than any semi-iron house they had ever built.

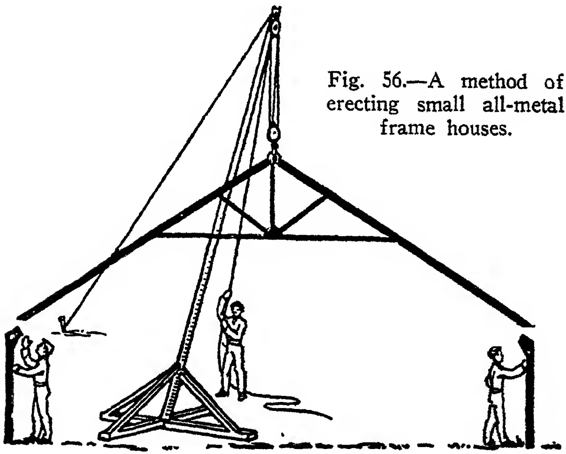


Fig. 56.—A method of erecting small all-metal frame houses.

Structural steel is most largely used in truss-frame houses though gaspipe is now quite popular. It is claimed for gaspipe that it costs less than structural steel and that it casts less shade. Some objection has been urged against houses constructed of gaspipe on account of a lack of rigidity, but as now constructed they give very satisfactory service. Houses of this type are

regularly supplied by manufacturers up to 54 feet in width, without center supporting posts. It is probably safest to have two rows of supporting posts in houses more than 40 feet in width.

CHAPTER VII

GLAZING AND PAINTING

Greenhouse glazing is an art in itself. Most construction firms employ professional glazers. It is, however, an art that may be readily acquired. Many owners do their own glazing when occasion requires, or have it done by their ordinary help. The method of glazing greenhouse roofs is not the same as that used in glazing window sash. When glazers from glazers' shops or hardware stores are employed, precaution should be taken to see that they understand the difference.

Glass.—The glass commonly used in greenhouse glazing is clear, white, sheet or window-glass of either A or B grade. Glass with a pronounced green or bluish cast is to be avoided, as it obstructs a large part of the heat, light and chemical energy of the sun's rays.

Clear, white window-glass ordinarily absorbs about 30 per cent. of these rays; green, from 40 to 50 per cent.; and blue, from 50 to 80 per cent.

Glass known as A, or first grade, is blown from the top of the retort and is of better quality than the B, or second grade, which may contain some foreign matter or settlings. Some of the less regular panes from the first blowing and those containing small air bubbles are also placed in the B grade. When it is essential that the greatest possible amount of light be had and tight glazing is necessary, A grade is used.

In most commercial constructions B grade will give satisfactory results. Poorer grades are not satisfactory for greenhouse work. The cost of B grade is about 85 per cent. of the price of A grade. Both A and B grades may be had in two weights or thicknesses, known as single-thick and double-thick. Single-thick runs about 12 panes to the inch and weighs from 19 to 21 ounces per square foot. Double-thick runs about 8 panes to the inch and weighs from 26 to 29 ounces per square foot. Double-thick is almost always used when the panes are more than 8 x 10 inches in size. It obstructs but little more light and is much more durable, especially against hail.

The price of single-thick is from 60 to 70 per cent. of the cost of double-thick. American window-glass is the best that can be procured. The price varies greatly from year to year,

probably more than does the price of any other standard building material.

American-made glass is packed in boxes of about 50 square feet each. Foreign glass comes in boxes of approximately 100 square feet each. The number of lights per box of the various sizes of American-made glass is shown in the following table:

LIGHTS PER BOX ACCORDING TO SIZE

Size	Lights per box	Size	Lights per box
7 x 9	114	14 x 16	32
8 x 10	90	14 x 18	29
8 x 12	75	16 x 20	23
10 x 12	60	16 x 24	19
10 x 14	51	18 x 18	22
12 x 12	50	18 x 20	20
12 x 14	43	18 x 24	17
12 x 16	38	20 x 20	18
14 x 14	37	20 x 24	15

Plate glass is seldom used in commercial greenhouses, as its cost is prohibitive. It is but little better than A grade window-glass for this purpose. In conservatories where strength is more important than transparency, fluted or corrugated glass, or glass into which wire netting has been blown is sometimes used. Ground or frosted glass is occasionally used in palm-houses or ferneries, where a soft, subdued light is desired. This effect is more commonly

obtained by painting or whitewashing the clear glass and varying the thickness of the coating according to the season of the year.

Size of Glass.—The size of the glass varies according to the purpose for which the house is to be used, and the taste and personal preference of the owner. Where extreme lightness is wanted, large panes are used thus diminishing the number of sash bars. There is, however, a practical limit to the size. Glass increases rapidly in price as the size increases, and the large panes break more easily. Moreover, the size of the sash bars must be increased to carry the extra weight, and every increase in their size means more shade.

Glass 16 x 20 is preferred by most growers with sash bars set 16 inches apart.

Methods of Glazing.—Practically all methods of glazing make use of putty to seal the glass in place and to form an air and water-tight joint. An exception is made when some forms of metal bars are used. With these, felt, candle wicking or some similar material is usually employed, and the glass is pressed firmly against it and kept in place by bolts or clamps. Sometimes a lead facing is used and the glass is clamped against this facing.

The great majority of houses are constructed

with wood sash bars or bars having wood cores with which putty is supposed to be used. With these there are two common methods of setting the glass. It may be lapped or butted.

Lapped Glazing.—In lapped glazing the lowermost panes in each run are laid flat against the bottom of the grooves in the sash bar. Each succeeding pane is then laid so that its lower edge laps over the upper edge of the pane below it, in much the same way that shingles are lapped, except that the lap is much narrower. From one-eighth to three-eighth inches are allowed for lapping, the width of the lap depending somewhat on the size of the glass and the rigidity of the house and roof. It should be as narrow as possible, for little light passes through the lapped part of the roof.

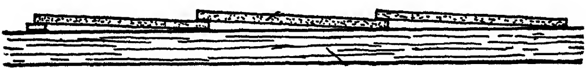


Fig. 57.—Lapped glazing.

Butted Glazing.—In butted glazing all panes lie flat against the bottom of the grooves in the sash bars, and the lower edge of each glass rests directly against the upper edge of the one below. This form of glazing eliminates the lap, but it is more difficult to obtain a tight

roof than when the glass is lapped. Roofs having a pitch of less than 30 degrees are likely to leak badly when the glass is butted.

In this form of glazing the putty is sometimes omitted, and the glass is held in place by wood caps which fit over the rabbets. When it is desired to make an especially tight roof, the upper and lower edges of the panes are sometimes dipped in a shallow tray containing thick paint. They are laid while the paint is soft, and in hardening this forms a tight, waterproof joint. Zinc glazing strips, bent in the form of a letter Z were at one time quite extensively used between the panes to make a tight joint. They are still used to some extent between the panes on side and end walls.

Several advantages are claimed for butted glazing: (1) Less glass is likely to be broken by accidents, for if only one pane is hit, it only will be broken; while if the panes are lapped, the one immediately below is often cracked. (2) Less glass is broken by the action of frosts, as there are no laps in which moisture can collect and freeze. (3) The roof is lighter, as there are no laps to obstruct the sunlight.

The chief disadvantage, aside from leakage, is the difficulty in repairing the roof when a glass is broken, for the pane must be cut to fit

tightly. In cold, stormy weather, this is a slow and tedious process.

Butted glazing is much less used than formerly among practical growers, which is proof that, in general, it is not so well suited for glazing roofs as is lapped glazing. More than 90 per cent. of the growers interviewed on this subject preferred lapped glass roofs. On side and end walls, glass is quite commonly butted with good results.

Putty.—Putty is a pliable substance used in setting glass. The principal ingredients are whiting and linseed oil, and its chief virtues are that it is easily worked and applied, and that it does not shrink on drying, thus making a watertight seal. For greenhouse use, putty as bought in the general market should be mixed with pure white lead at the rate of one part of lead to five of putty. This will stick to the bars and glass much better than will ordinary putty.

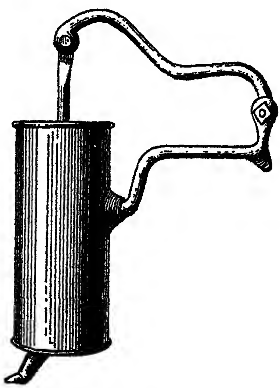


Fig. 58.—Machine for distributing putty.

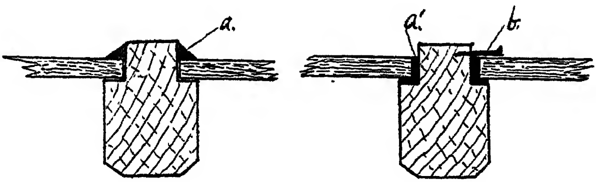
Putty purchased from dealers in greenhouse

supplies will not need the addition of lead. It should be worked as soft as it can be handled in order that it may be easily forced into all cracks and crevices. It is applied with a putty knife or with a putty machine. The putty machine distributes the putty rather more rapidly than can be done by hand, but it is necessary to use a putty knife in conjunction with it.

Special plastics have been developed to take the place of conventional putty in greenhouse glazing. It is claimed that they are easier to apply, that they remain soft and pliable so that they are easily removed when it is necessary to replace a broken glass, and that they do not chip or crack as putty often does. The makers of some of these materials recommend glazing on the outside the same as with window glass.

Setting the Glass.—The basic difference between glazing greenhouse roofs and glazing ordinary window-sash is in the method of applying the putty. In glazing window-sash, the putty is placed on the outside. In greenhouse glazing the putty is placed in the grooves in the bars and the glass is forced into it. That which oozes up around the edges is scraped off and used again. By this method, little putty is exposed to the air, but the glass is sealed by a thin film underneath and along the sides of each

pane. This method has been developed because experience has shown that on roofs putty soon checks and crumbles away when exposed to the weather as in window glazing.



A. B.

Fig. 59.—A, window glazing; B, greenhouse glazing. The putty is shown at a and b.

When glass is lapped, the following method is used. First, the sash bars should have been so placed that the space left for the glass is about one-eighth of an inch wider than the glass. This provides room for the "side putty." (For method of spacing see page 92). Sash bars are usually primed when received from the factory. They are given another coat of paint after they are put in place and are then ready for glazing.

Glazing is started at the bottom of the run. A line of soft putty is first placed in the rabbets and a pane of glass forced firmly into it until it is imbedded against the bar. A groove is usually provided in the plate to receive the

lower edge of this glass to prevent it from sliding down, but if there is no such groove, three or four brads or glazing points are driven for the lower edge to rest against.

The excess putty is then removed and the next glass forced firmly into place, so that its lower edge laps over and rests firmly on the top of the first, and its upper edge rests on the sash bar. This is fastened at the bottom with brads or glazing points to prevent its sliding down. The remaining panes of the run may then be placed in the same manner, special care being taken to secure the uppermost firmly in place with glazing points. This is necessary because it has no glass above it to hold it in place, and because it acts somewhat as a key to keep the others in position.

It is best to finish each run from bottom to top before starting on a new run, in order that the putty may cement into a continuous mass. On high and wide roofs, however, it is sometimes advisable to glaze the lower half of the roof, then move the scaffolding and glaze the remainder.

How to Estimate Putty.—The amount of putty necessary to glaze a roof may be estimated as follows: A pound of putty, when applied by an experienced workman, will reach

about 15 feet along one side of a run of glass or about 7½ feet along both sides. To estimate the amount of putty, therefore, multiply the length of the run in feet by the number of runs and divide by 7½. This will give the number of pounds required. The amount required for the sides and gable may be found in the same way. An inexperienced workman will use somewhat more than this amount as there will be more waste.

In glazing by the "butted glass" method, putty may or may not be used. When it is used, the method is very similar to that described above, except that much less is required, as the panes are crowded down to the bottom of the rabbet along their whole length instead of only at their upper end. Sometimes in glazing by this method no putty is used until after the glass is laid, and then a small quantity of liquid putty is forced down along the sides of the glass with a putty bulb. Usually when the glass is butted, the bars are surmounted by wood caps. In this system special care must be taken to fasten the lower pane, as

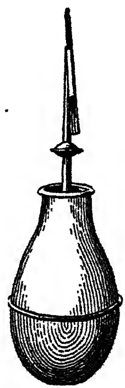


Fig. 60.—Putty bulb.

the sliding weight of the entire run rests against it.

Glazing Points.—Glazing points are used to hold the glass in place. They may be had in several forms and sizes. A good glazing point is easily driven, does not split the wood, offers as little obstruction as possible to the brush in painting and does not rust. Small sizes suitable for glazing window-sash in which the putty is placed on the outside are too small for greenhouse glazing. Zinc points of various forms have been frequently used because of their freedom from rust. The triangular point is probably the most popular of the zinc points, and is

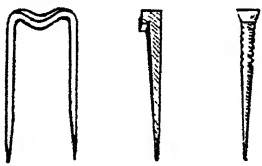


Fig. 61.—Types of glazing points.

quite commonly used in window glazing. It is not well suited to greenhouse glazing on account of the difficulty of fastening the panes of glass with it so that they will not slide down the roof.

Probably the most used point in greenhouse glazing is the double-pointed staple. This is

easily driven and when galvanized is not subject to rust. The best form of this type of staple is bent to an angle in the center, so as to fit over and hold the lower edge of the pane from slipping lengthwise, as well as to hold it down in place.

In lapped glazing only two double points are used for each pane, that is, one at each lower corner. The upper edge is kept in place by the

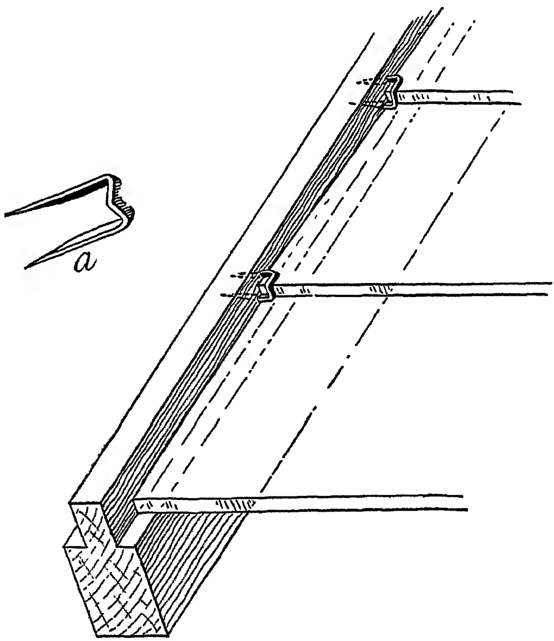


Fig. 62.—Glazing with double glazing points.

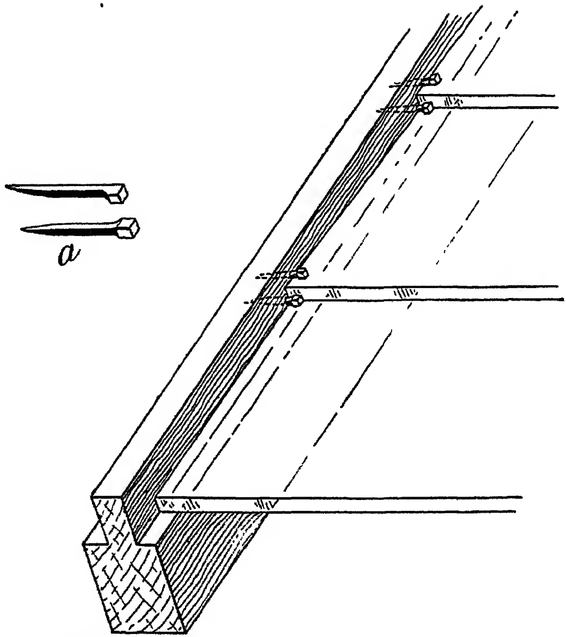


Fig. 63.—Glazing with single glazing points.

bottom of the pane above it. Additional points are required for the lowermost and topmost panes in each run, and as some will be lost and destroyed, it is well to figure on three staple points for each pane. An average of five of the small single points will be required for each pane.

Precautions.—All sheet glass is slightly curved, a condition caused by the process of

manufacture. When seconds or B grade glass is used, it will sometimes be found that the panes will be so much curved as to make it difficult to lay a tight roof. If this trouble is experienced, it will be of advantage to sort the glass and lay out each run on a smooth floor, placing the panes having a similar degree of curvature in the same run. By doing this a tighter and more satisfactory roof can be laid.

Theoretically, the glass will resist more pressure if it is placed so that the curve will be up, that is, so that it will present a convex surface to the weather. If, on the other hand, it is placed so as to present a concave surface to the weather, the water will have a tendency to flow away from the sash bars and putty to the center of the runs. In actual practice, these are relatively unimportant considerations, but all glass in the same run should have approximately the same curvature.

Liquid Putty.—This is sometimes used for sealing cracks in old glazing or in glazing by the "butted" method. It may be made as follows: Take equal parts by measure of white lead, putty and boiled linseed oil. First, mix the putty and oil thoroughly and then add the lead. If it becomes too thick, thin with turpentine.

PAINTING

. Probably few other structures require as careful or as frequent painting as do greenhouses. This is due: First, to the moist condition of the air in the house, which favors the decay of the wood; and second, to the difference in temperature between the outside and inside of the house, which often causes excessive contraction and expansion of the structural material. It is especially important that all joints in the framework be thoroughly coated when they are put together, and that they be well painted in order to prevent moisture from entering. As a rule, greenhouses should be painted one coat both inside and outside every second year, and inside portions which are especially exposed to dampness and shade should be painted every year, care being taken to see that they are dry when painted. Nothing has yet been found which will excel pure white lead and oil with a turpentine dryer for this purpose.*

* On this point commericial greenhouse builders do not agree. One of the largest firms in the country uses a paint containing 10 per cent. of French zinc and finds it the most satisfactory paint they have ever used. Another well-known firm after experimenting with lead and zinc in varying proportions has gone back to pure lead. The tendency of zinc paint is to crack and peel, and of pure lead paints to become chalky

For the outside the intense white may be softened by the addition of a little lampblack or other coloring material, but for the inside, colors are avoided, as they have a tendency to absorb light. Pure white is undoubtedly best for interior painting.

Greenhouse woodwork when received from the factory has usually been given a priming coat. By special arrangement it is often possible to have it treated in a bath of hot linseed oil. If the woodwork has not been primed when received, it is preferably so treated before it is erected. Either pure, thin linseed oil, or a mixture of oil and yellow ochre is used for this purpose. As soon as erected, the whole framework is painted inside and out before glazing. After glazing another coat is applied. Because of the frequent painting necessary, it is seldom advisable at the time of erection, to apply more than two coats in addition to the priming coat.

Many manufacturers supply structural members of wood other than cypress or cedar which have been treated to resist decay, (See Chapt. III). If well treated they give satisfactory service but contrary to prevailing opinion they should be painted the same as untreated wood.

Paints for Iron Work.—Paints used for wood may be used for painting iron and steel

provided the parts to be painted are free from rust and grease. To paint iron and steel wash off all grease with gasoline and sand off all rust. Next coat with a primer to prevent further oxidation or rusting. The best paint for this purpose is red oxide of lead. If this is unobtainable a satisfactory priming coat may be made by melting together three parts of lard and one of resin. This is brushed on thinly while hot. Shellac may be used but the cost is likely to be prohibitive except for small jobs. After priming any good paint may be applied.

It is now well established that the bronze or aluminum "radiator paints," formerly used for radiators and for steam and hot water pipes, interfere with the radiation of heat and are no longer recommended. Ordinarily steam and hot water pipes in greenhouses are left unpainted. When it is desired to paint them, any good paint is satisfactory if the pipes are first given a priming coat of red lead. Special paints are also made for painting radiating pipes. Allow the paint to become thoroughly dry before turning on the heat.

Amount of Paint Required.—This varies according to the kind and condition of the surface to be painted, and to some extent with the kind of paint used. Painters usually figure that

a gallon of mixed paint will cover 250 to 300 square feet of white pine or cypress the first coat, and 350 to 400 square feet the second coat.

A general rule for determining the amount required is as follows: Divide the number of square feet of surface to be painted by 200, the result will be the number of gallons of liquid paint required to give two coats.

Another is: Divide the number of square feet by 18. The result is the number of pounds of pure, ground, white lead necessary for three coats.

Shading.—During the summer the heat becomes so intense in a greenhouse that some shade must be given if plants are to be grown satisfactorily. This may be accomplished by the use of muslin curtains in the inside of the house or by lath screens laid upon the roof. The most common method in commercial houses is to apply some kind of a coating to the outside of the glass which will be washed off by the late fall rains. Some form of whitewash is most satisfactory.

The author prefers a wash made of freshly-slacked stone lime and water, to which is added one part of common salt to four parts of lime. The salt is added after the line is slaked. This is then strained and applied with a spray pump.

It is usually necessary to apply this two or three times during the summer, but it comes off readily through the action of the fall rains and frosts and seldom requires the use of a scrub brush.

Another paint sometimes used is composed of white lead and gasoline, just enough lead being used to make a milk-colored liquid. This may be applied with a brush or with a spray pump. It adheres much better than the wash mentioned above, but is open to the objection that it is sometimes necessary to do considerable hand work to remove it in the fall.

A third wash sometimes recommended is made as follows: Slake a half bushel of stone lime. Strain and add a brine made of one peck of salt in enough warm water to fully dissolve it. Then add three pounds of rice flour, and boil to a paste. Then add a half pound of whiting and one pound of glue dissolved in warm water. Mix thoroughly and let stand for a few days, thin with water, and apply. This is the whitewash commonly used for painting fences and buildings and is very adhesive. For greenhouses it is applied in a very thin coat.

Brackets.—In glazing and painting the outside of a roof, a common means of support for the workman is a plank or ladder supported by

brackets resting on the sash bars or on every other sash bar.

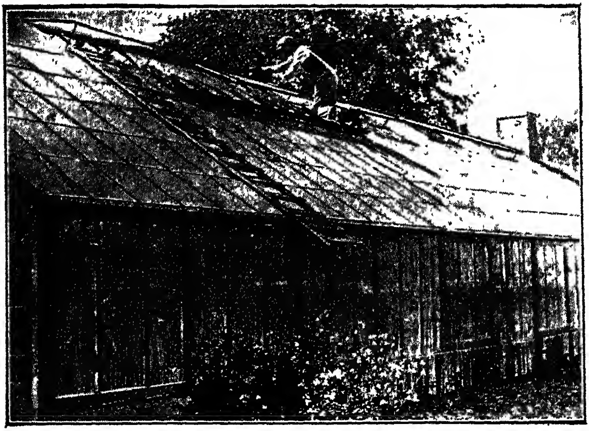


Fig. 64.—Glazing ladder used in glazing and painting.

Glazing Ladder.—Another device used more in painting than in glazing is a ladder made by nailing cleats on one side of a plank for foot holds, and on the other side longer cleats so that they will rest across at least two sash bars and thus distribute the weight. The ladder is held in place by hooks which reach over the ridge.

CHAPTER VIII

VENTILATION AND VENTILATING MACHINERY

Greenhouse ventilation has not yet been worked out with the same care and precision as has the ventilation of dwellings, public buildings, or even barns for the use of live stock. On the other hand, greenhouses are seldom or never built without some special attention being given to the question of ventilation, whereas, dwellings and even public buildings are often erected without any reference whatever to this important subject.

This anomaly may be partly explained by the following facts: (1) The transpiration of plants is not so well understood nor is it so easily measured as in the transpiration of animals. (2) Windows are necessary in dwellings and public buildings to admit light and they may be utilized, when necessary, to provide ventilation. (3) In greenhouses, ventilation is not only provided for the purpose of maintaining a supply of fresh air, but is utilized as a

method of controlling temperature and humidity. (4) Greenhouses, because of their transparent roofs, are much more liable to sudden or violent changes in temperature (especially in days of alternate clouds and sunshine) than are dwellings, and the necessity for ventilation in order to equalize the temperature is evident. (5) Greenhouse plants are, as a rule, particularly sensitive to cold drafts, and ventilation cannot be left to the indiscriminate opening of doors.

Systems of Greenhouse Ventilation.—There can hardly be said to be any well defined systems of greenhouse ventilation, as compared with the so-called systems of ventilation for public buildings. Greenhouse ventilation rests on the principle that warm air has a tendency to rise, and since the air within the greenhouse is considerably warmer than that outside, during both summer and winter, the question of changing the air presents no serious problem. It is only necessary to provide a means for the warm air to escape. The cooler air from the outside easily finds its way into the house through the numerous small openings between the panes of glass.

Side Ventilation.—Side ventilation is of little service, except during the summer months,

as the opening of these ventilators in winter would expose the plants to a direct current of

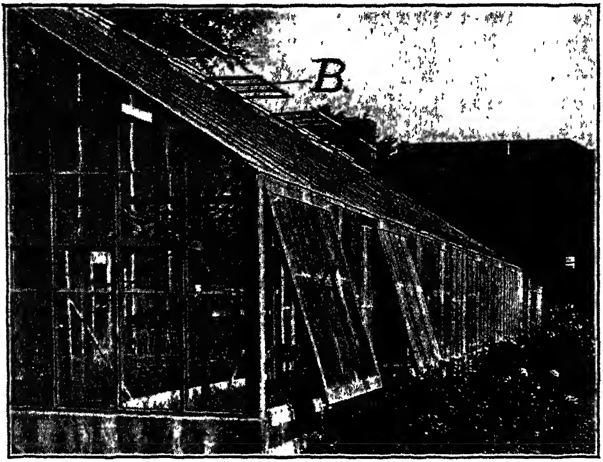


Fig. 65.—Greenhouse showing A, side ventilators; B, overhead or roof ventilators.

cold air which would prove fatal. Side ventilating sash are usually hinged at the top and open outward and upward. Probably less than 50 per cent. of the commercial houses in the country are equipped with side ventilation, though it is often convenient in spring and summer. An ingenious method is sometimes employed in conservatories whereby the air is taken in from below the benches and is warmed by passing over the heating pipes. Thus the danger of

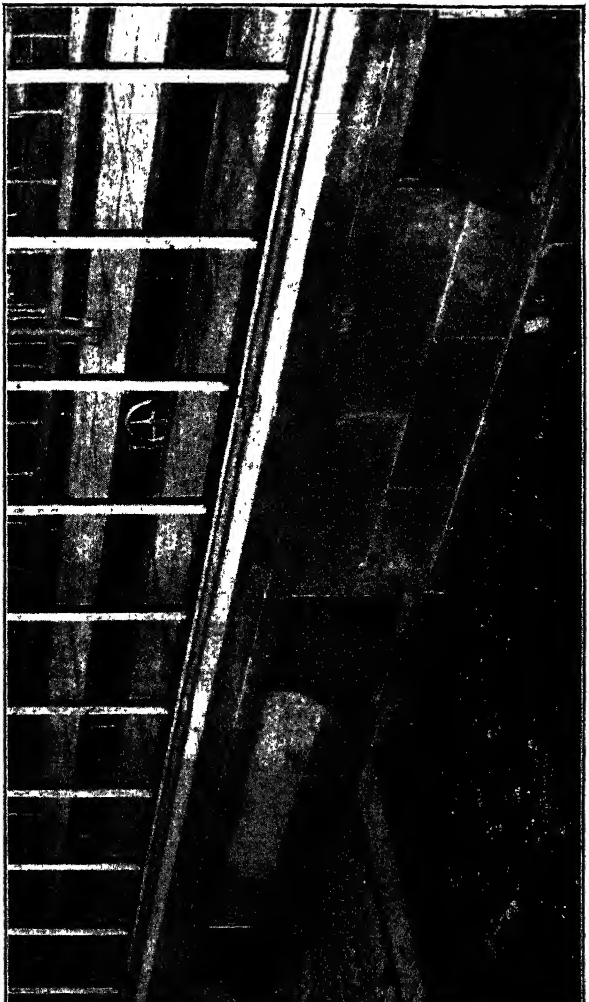


Fig. 66.—Method of under-bench ventilation.

injury to the plants is greatly lessened. (Fig. 66).

Overhead Ventilation.—During the winter practically all the ventilation of greenhouses is accomplished by means of overhead ventilators set in the roof at or near the ridge. These ventilators are in the form of sash hinged on the outside, and may be closed down tightly over the sash bars or opened to any degree desired. As the warm air naturally rises, the opening of these ventilators allows the warmest air of the house to escape, and fresh cool air to filter in through the crevices between panes of glass without causing excessive drafts.

Experience shows that these ventilators need to be relatively narrow and practically continuous along the whole length of the house, rather than intermittent, as the presence of occasional large openings is more likely to cause drafts of cold air. They are preferably glazed with glass of the same width as used for the roof and they should be placed so that the bars of the ventilating sash will be directly over the sash bars.

Size of Ventilators.—No definite rule can be given as to the size of ventilators, as so much depends on the location and arrangement of the house, the kind of plants to be grown, etc. Experience has shown that where the ventilators

are continuous along the entire length on both sides of the roof, the following sizes are sufficient.

Size of house	Width of ventilating sash
Up to 40 feet wide	24 inches
Above 40 feet wide	30 inches

This is the rule followed by most greenhouse builders.

Methods of Hanging Sash.—Ventilating sash may be hung so as to open either at the top or bottom; that is, they may be hinged at the lower side so as to open out and away from the ridge, or they may be hinged at the ridge so as to open upward from the lower side. Both

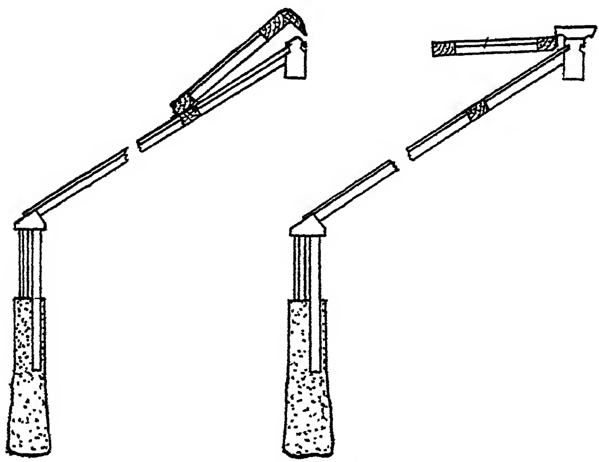


Fig. 67.—Two methods of hanging ventilator sash.

methods have their advantages and disadvantages. Sash opening at the ridge have the advantage that the air will escape more rapidly when the ventilators are opened, as there is but little obstruction and the opening is at the highest part of the house. There is also less tendency, when ventilators are used on one side of the roof only, for unfavorable winds to blow directly into the house.

The practical disadvantages of this method of hanging is that the ventilator sash are more likely to be torn off by severe storms than when hinged at the top, and also that it is more difficult to prevent leakage at the ridge. The prevailing tendency is to hinge the sash at the ridge and in houses 30 feet wide or more to provide ventilators on both sides of the roof.

Operating Machinery.—Since the ventilating sash are placed at the highest part of the house, and as it is necessary to change the size of the opening several times a day, it is obvious that it is highly desirable that some method be provided by which they may all be opened and closed from some point convenient for the operator. This is accomplished by means of various types of sash-operating machinery.

The essential features on which most types of ventilating machinery depend are as follows:

(1) A horizontal shaft firmly fastened near the line of ventilating sash; (2) a system of gearing, by which power applied at a point convenient to the operator may be transmitted to and rotate this shaft; (3) arms or levers attached to the shaft and also to the sash, and so arranged that the sash are raised or lowered when the shaft is rotated.

Shafting.—The shafting generally used is one inch or one and a fourth inch gaspipe. The

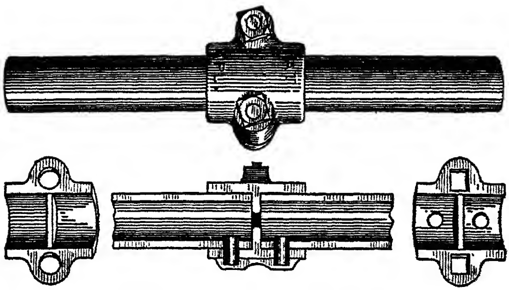


Fig. 68.—Malleable iron shaft couplings.

lengths are either riveted or clamped together by special couplings so that the shaft will be perfectly rigid. A method sometimes used is to screw the lengths of pipe into an ordinary sleeve coupling as far as they will go; drill a hole through each end of the coupling and pipe, and rivet all together with tight-fitting rivets.

This method is less satisfactory, however, than the use of split malleable iron castings several forms of which are to be had. These castings are longer and stronger than the usual sleeve coupling and they thus have a firmer grasp on the pipe.

They usually have pins or lugs cast in the inside which fit into holes drilled in the pipe at the proper positions, and the two parts are clamped tightly in place by means of bolts. A special advantage of this method of coupling is that the shafting may be put up in sections and clamped together after being put in place. Square or round, solid shafting is sometimes used, but it has less torsional or twisting strength, weight for weight, than does good wrought-iron or steel pipe. Wrought pipe comes in two weights, standard and extra heavy. It is safe to use the different sizes and strengths as follows: Shafts up to 50 feet in length, 1 inch standard strength; shafts up to 75 feet in length, 40 feet of 1 inch extra heavy, and 35 feet standard strength; shafts up to 125 feet in length, 1¼ inch all extra heavy.

Shaft Hangers.—The shafting is held in place by means of hangers. These hangers may be fastened to the rafters, to the sash bars or to the supporting posts. In iron frame houses it

is customary to hang overhead shafting from the rafters and the shafting for the side ventilators from the side posts, using a hanger for

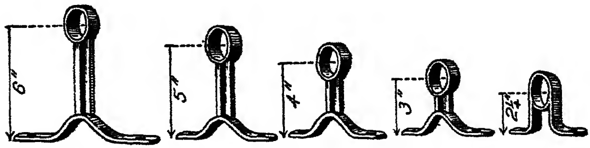


Fig. 69.—Shaft hangers.

each rafter or post. When the shafting is hung from the sash bars a hanger is attached to every second or third bar, usually to every second.

Gearing.—Generally speaking, there are three types of gearing utilized for operating overhead ventilator shafting. These are: (1) The column gear, of which there are many different forms; (2) the chain-operated gear; and (3) the rack and pinion gear.

In the column gear a post or column supports the gearing and the wheel to which the power is applied. One form of column gear is known as an open column gear, because the drive rod is not inclosed in the column and there is no housing about the gearing. In another open column gear type a chain is used to transmit the power. In the closed column types all gearing is enclosed and runs in oil, much the same as

in the transmission case of an automobile. This insures freedom from noise and ease of operation.

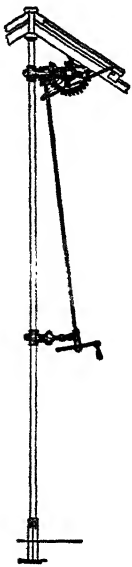


Fig. 70.—Open column ventilator gearing.

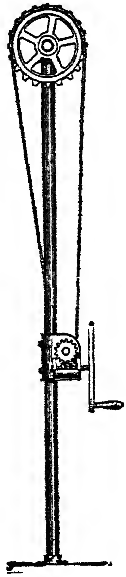


Fig. 71.—Open column chain operated ventilator gearing.

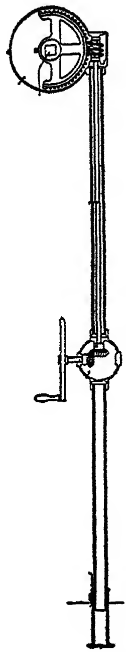


Fig. 72.—Closed column ventilator gearing.

In the chain type no columns are required, a feature much prized by growers. By this system practically all the ventilators in a house may be operated from one point, as the chains may be run almost anywhere in the house by

the use of pulleys. The absence of columns means less shade.

The rack and pinion type differs from the two general types mentioned above, not so much in the method of applying the power to the

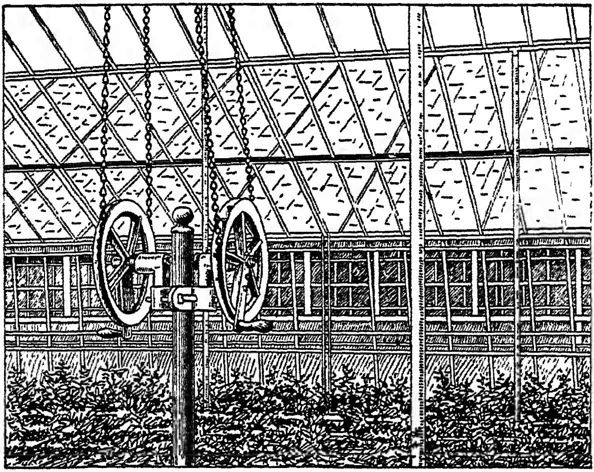


Fig. 73.—Chain system of operating ventilators. No columns used.

shaft as in the method of actually opening the ventilators. The chief advantage of this system lies in the fact that there is less torsional or twisting strain on the shafting than when the usual method is employed, and they are more powerful. The chief disadvantage is that provision must be made for giving the shaft sev-

eral revolutions, while a half or two-thirds revolution is usually sufficient with the more common forms.

Some practical growers claim that the rack and pinion device is very subject to wear and is a frequent cause of trouble. This is more especially true of the older forms of this type. The fact that they are not generally used would

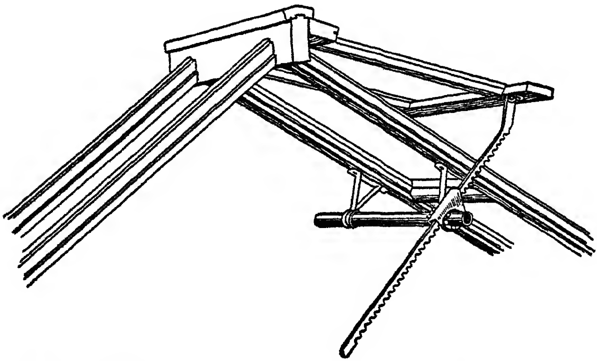


Fig. 74.—Rack-and-pinion system of operating ventilators.

seem to indicate that practical growers as a rule are not yet convinced of their superiority, though they are now being installed in some large houses where it is necessary to operate long runs.

Quite frequently the hand wheel and gearing are fastened to the rafters or purlin posts and no extra columns are required.

Side Ventilating Machinery.—The essential features of side operating machinery are the same as for overhead ventilators. When there are side benches a shaft is usually used and the hand wheel placed at a convenient

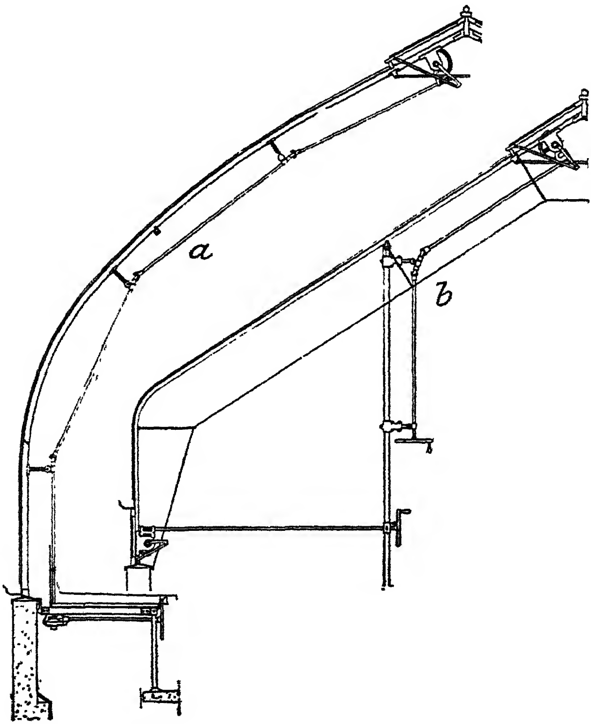


Fig. 75.—Ventilators (a and b) operated by means of rods with universal joints attached to posts and rafters. No extra columns are necessary.

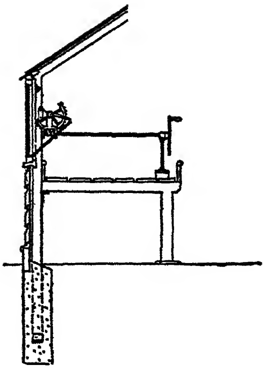


Fig. 76.—Device for operating side ventilators.

position for the operator. When there are no benches along the sides a compact device is advisable in order to take up as little room as possible (Fig. 77).

Ventilator Arms.—Ventilator sash are most commonly raised and lowered by means of hinged braces or arms operated from the shafting. There are three general types. (Fig. 78).

The elbow arm is most commonly used but has the disadvantage that a long leverage is required, in order to open the ventilators to the full width, which puts a considerable strain on the shaft.

The double acting arm overcomes this difficulty to some extent as it is possible to secure a wider opening with a shorter leverage, but it is necessary to rotate the shaft through an extra half turn. On long runs these arms are now being extensively used in place of the common elbow arm.

The extending arm is used in low houses, or for side ventilators, or in other places where an

elbow or double acting arm would extend into the house so far as to be in the way. It folds together when the sash is closed and occupies little space, but it extends automatically when the shaft is turned. It is especially convenient

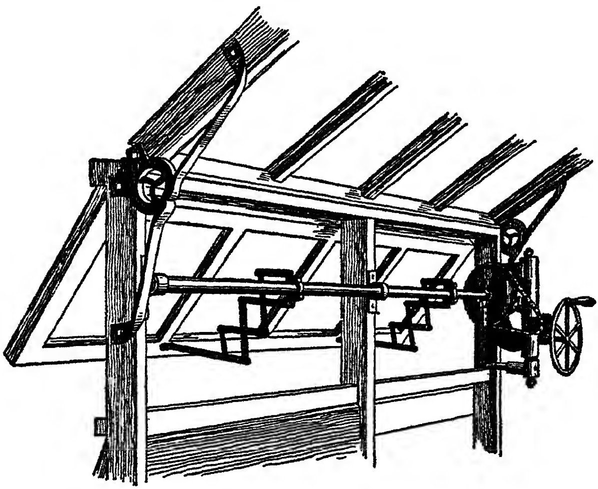


Fig. 77.—Compact machine for operating side ventilators.

under certain conditions, but it lacks the strength necessary for long runs.

In all systems the arms are clamped securely and rigidly to the shafting, and as near as possible to the hangers so as not to spring the shafting when heavily loaded. They are spaced about 3 feet apart along the sash. If continuous

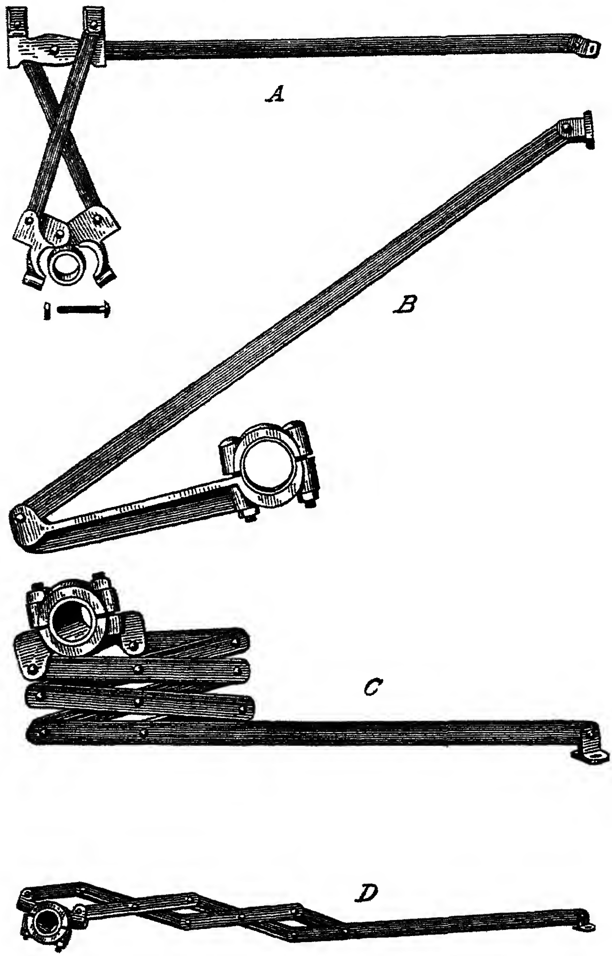


Fig. 78.—Types of ventilator arms. A, double acting arm; B, elbow arm; C, extending arm closed; D, extending arm open.

sash are not used the arms should be distributed as follows: For sash up to 4 feet long, one arm; from 4 to 7 feet long, two arms; and from 8 to 11 feet long, three arms, etc.

Capacity of Ventilating Apparatus.—The capacity of ventilating apparatus depends largely upon the size and method of manufacture, but the length of run is limited to the torsional strength of the shafting. In long lengths there is always more or less torsion, so that the ventilators at the extreme end do not open as wide as those close to where the power is applied. This is of little consequence in summer when the ventilators are wide open, but in winter, when only slight ventilation is required, it may result in the sash at the end of the shaft not opening at all and the ventilation will thus be uneven and unsatisfactory. Moreover, the sash are likely to be frozen down in winter and the tendency for the shafting to twist is thus increased. It is wise to have a wide margin for safety.

An indication of the length of shafting that may be used with safety is given on page 132. Tests show that one and a fourth-inch standard pipe has a torsional strength 42 per cent. greater than 1-inch double-strength pipe and that the weights are practically the same. The

price of 1-inch double-strength pipe averages about 25 per cent more than standard one and a fourth inch pipe. It is evident, therefore, that for long runs it is not only safer but more economical to use one and a fourth-inch standard pipe than 1-inch double-strength.

Generally speaking, a 150-foot run is about the limit when elbow arms are used. This may be slightly increased by using the double acting arms, and still further by using the rack and pinion system. This is equivalent to saying that the ventilators in a house 300 or 350 feet long may be operated from one station by having machines located in the center of the house and operating each way. It is economy to have all ventilator sash for one house operated from the same station if possible.

Sliding Shaft System.—In order to enable the operator to care for an extremely long line of sash from one station a sliding shaft system has been devised. In this case the shafting is solid and square, and instead of rotating it slides backward and forward, the motion being given by a pinion working on a screw or worm gear at one end of the shaft. This sliding movement is utilized to operate the sash by means of a right angle lever, pivoted at the angle with the short arm attached to the shaft and the long

arm to the sash. It is claimed for this system that it will operate a line of sash 500 feet long.

Automatic Ventilation.—Some installations have been made which provide for automatic ventilation by using an electric motor to power

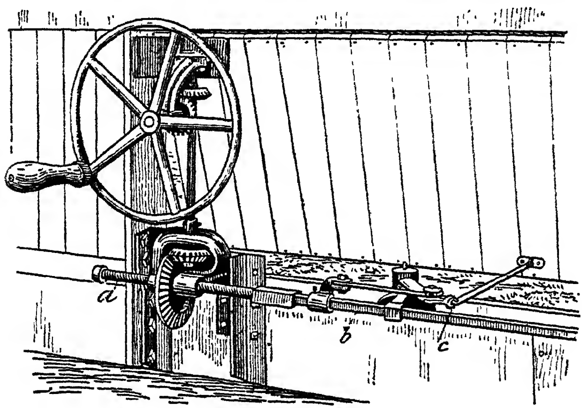


Fig. 79.—Sliding shaft system for operating ventilators.

the ventilating machinery and connecting it to a thermostat. The thermostat is set so as to start the motors and raise the ventilators when the temperature in the house reaches a certain high point and to close them when it reaches a certain low. Motors may be installed to take the place of the hand wheel or crank used to operate the ventilators manually or they may be attached to shafting placed near the top of the

house thus doing away with all gearing and shafting in the lower part of the house.

In general these automatic systems have been quite satisfactory. They save much labor, especially on days when there are rapid fluctuations of temperature caused by alternate bright sun and clouds. Some growers have experienced some breakage when the ventilators have become frozen down as sometimes happens. This may be avoided by the use of an automatic throw-out which cuts off the current when the strain becomes too great or by making use of a shearing pin. Shearing pins may be easily replaced if the motor is installed in place of the hand operating wheel or crank but are less easily replaced when the motor is installed on the shafting in the peak of the house.

CHAPTER IX

BEDS, BENCHES AND WALKS

In the earlier greenhouses, plants were almost always grown on raised benches. This was partly for the convenience of the grower and partly because the houses were almost always erected with high, solid side walls and it was necessary, in order to secure satisfactory growth, to bring the plants close to the glass roof. In modern houses, when all or part of the side walls are of glass, raised benches are not so necessary, and are very commonly dispensed with and the plants grown directly in the soil which forms the floor. This is particularly true when vegetables such as lettuce, tomatoes or cucumbers are grown.

Florists, as a rule, have been loth to give up the use of benches and present the following arguments in their favor. (1) It is more convenient to care for plants when grown on raised benches than when grown on the ground. (2) Benches make possible the placing of the heating pipes underneath, which makes them less

conspicuous and at the same time affords a method of giving "bottom heat," which is considered advantageous with many plants. (3) It is maintained that there is a better circulation of air about plants grown on benches and that the plants are less subject to disease. (4) The temperature and moisture of the soil can be more easily regulated in benches. (5) Low-growing plants make a better display when grown on benches.

The following are the most common disadvantages claimed by those who urge against the use of benches. (1) They are expensive to build and maintain. (2) They do not admit of an economical use of space. (3) The soil dries out rapidly. (4) The soil has to be changed more often. (5) It is more difficult to use labor-saving tools such as wheel-barrows. (6) All work must be done by hand. In large houses it is possible, when plants are grown on the ground, to prepare the soil with a horse or with wheel hoes. (7) With high-growing plants such as tomatoes and cucumbers, it is difficult to harvest the crop when they are grown on high benches.

Raised Beds.—To overcome some of the objections to raised benches, many growers use solid raised beds, the height varying from a few

Fig. 80.—Cucumbers growing in the ground. No benches are used.

inches to that common for benches. Such beds dry out less quickly than do benches, the soil does not have to be removed as frequently, and they are less expensive to maintain. They are open to some of the objections urged against benches and do not possess many of the advan-

Fig. 81.—Tomatoes growing in solid raised beds.

tages afforded by culture in the open soil. The width and arrangement follows closely that of benches.

Raised Benches.—Benches are exposed continuously to conditions which favor their rapid deterioration. Unless well constructed of good material, they are a source of constant annoyance. Many growers use wooden benches.

Others use benches having iron frames, and sides and bottoms of wood, tile, slate or cement slabs. Still others use solid concrete benches. All forms have their advantages and their advocates.

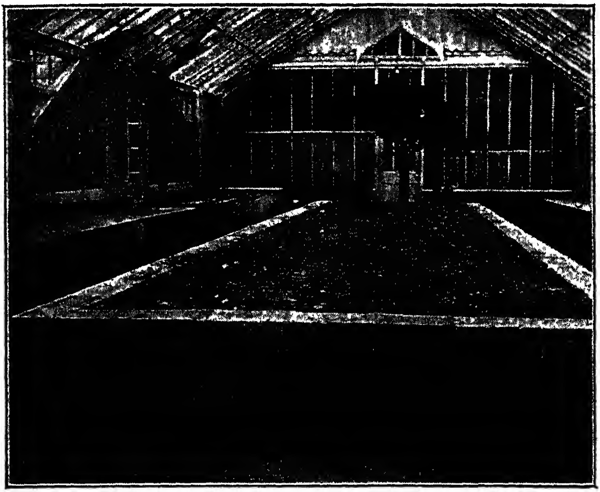


Fig. 82.—Solid raised beds of hollow building tile.

Wood Benches.—Wood benches have the advantage of slightly less first cost, though if good material is used, the cost will be nearly as great as for iron frame benches. In permanent houses nothing but cypress or cedar should be used, genuine pecky cypress being undoubtedly the best. The sides and bottom boards are not

less than 1 inch thick. The side boards are 8 inches wide. The width of the bottom boards is immaterial, except that when in place they have a space of a fourth-inch between them for drainage. They are usually run lengthwise of the bed and are supported by cross beams, spaced not more than 4 feet apart.

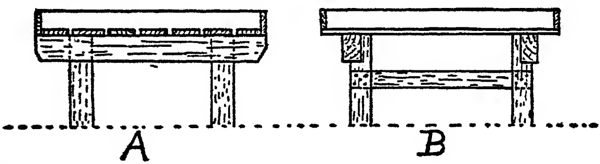


Fig. 83.—Two types of wood benches. A, bottom boards running lengthwise; B, bottom boards running crosswise.

The size of the cross beams will depend somewhat on the width of the bench, as follows:

For benches up to 4 feet wide..........	2 x 4 inches
For benches from 4 to 6 feet wide......	2 x 6 inches
For benches over 6 feet wide...........	2 x 8 inches

The legs or posts are at least 4 x 4 inches in size, and rest on concrete or brick piers. Sometimes, when cement walks are used, they are made to extend under the benches far enough to act as a foundation for the posts.

To guard against warping of the side and end boards of wood benches, angle irons may be used in the corners and along the sides, and

fastened by screws or small bolts. Brick piers may be used in place of the wooden legs. The wooden legs, however, will usually outlast the bottom boards and cross beams.

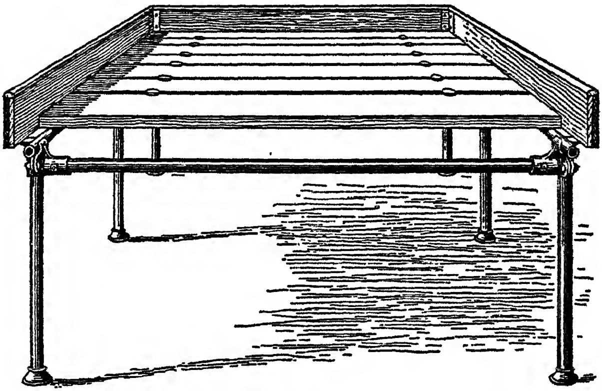


Fig. 84.—A type of iron frame bench.

Iron Frame Benches.—In the majority of iron frame benches, 1-inch wrought-iron pipe is used. It is rarely threaded but is tied together with split malleable iron castings by the use of bolts and set screws. The sides and bottom may be made of wood, iron, slate, tile or even of cement slabs. All are removable and may be replaced without taking down the frame.

Iron frame benches with cypress sides and bottoms are now much in favor. They are but

little more expensive than the all-wood benches and are in most cases more satisfactory, as the frames are nearly indestructible. They should, however, be made of wrought-iron pipe rather than of steel. They may be had in two forms, one in which the bottom boards run lengthwise of the bench and another in which they run crosswise. The advantage of the latter is that short lengths may be used. These benches may be purchased with all parts cut to order, or they may be easily cut by anyone familiar with pipe cutting.

Iron frame benches are also made of angle iron or structural iron of different forms. The chief disadvantage of these is that the iron cannot be worked readily by the ordinary workman and must be cut and fitted at the factory.

Concrete Benches.—Concrete, because of its permanency, is often recommended for greenhouse benches, and its use is increasing. In general, there are two separate types. In one type the legs, bottom and sides are cast separately in molds and then put together in the greenhouse. In the other type the whole bench is cast in a form built in the house where it is to stand. There are at least two firms having patents on cement greenhouse benches and who are prepared to sell or rent molds or forms for

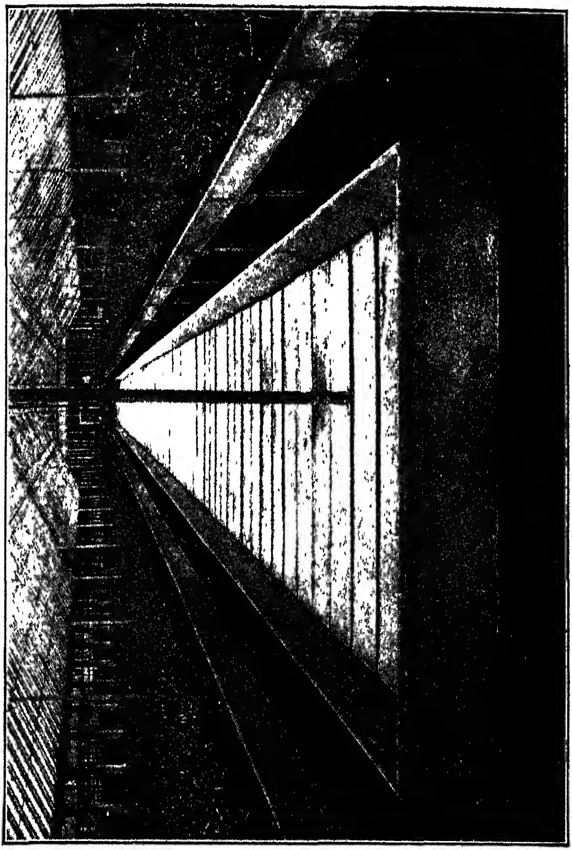


Fig. 85.—Greenhouse bench of concrete. The bottom is made of slabs of concrete.

making them. It is also possible for a skilled mechanic to make forms to suit any special location or for any form of bench. In making concrete benches, care should be taken to provide for adequate drainage through the bottom and to see that they are thoroughly reinforced.

There has been some discussion as to the effect of concrete benches on the growth of plants. The author has had but little practical experience with them but quotes from one of the largest users of concrete benches in the country, as follows:

"At my place I use only concrete benches and the results and advantages have been very satisfactory, but I want to be open and frank concerning the disadvantage, which is only for the first year. Something in the line of a chemical of a whitish nature appears on fresh new cement, and that seems to be injurious to plants; but after you have filled the benches with soil and used them the first year, the soil generally eats or absorbs this chemical, and the roots of carnation plants or anything else cling to the cement slabs the same as they do to slate. A good remedy to get rid of this so that it will not injure the plants is simply to put air-slaked lime or rather heavy whitewash on the inside of the bench, and that seems to protect the plants

from coming in contact with the chemical mentioned."

Height and Width of Benches.—The height of greenhouse benches is largely determined by that most convenient for the operator to work. This in turn depends upon the nature of the plants to be grown. For example, when low-growing plants like lettuce are grown, a bench 32 inches high is about right; but when carnations are grown this may be so high as to make disbudding difficult. This refers to the distance from the top of the walk to the top of the sides of the bench.

The width of the bench depends on the width of the house, on the arrangement of the benches, and to some extent on the kind of plants to be grown. It is limited to the distance a man can conveniently reach in caring for the plants. This distance is about 2½ feet or rarely 3 feet. In other words, benches that can be worked from one side only should be no more than 2½ or 3 feet wide, and benches which may be worked from both sides should be no more than 5½ or rarely 6 feet wide. In uneven span houses it is sometimes advisable to elevate the walks and benches.

Arrangement of Benches.—This is governed by the width of the house, the use for

which the house is designed, the height of the beds or benches and by the individual preference of the owner. Commercial growers look upon walks as waste space and endeavor to keep them as narrow as is consistent with ease and economy in getting about the houses. In private

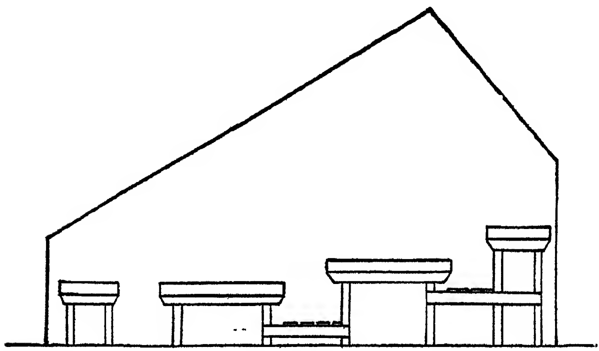


Fig. 86.—Method of arranging benches in an uneven-span house to secure best advantage of the sunlight.

houses, conservatories and show houses, the walks are sufficiently wide to allow two persons to pass easily.

In figures 87 and 88 are illustrated two methods of arranging benches in a 30-foot house. By the first method four benches, each five feet wide, are provided and 66⅔ per cent of the floor space is available. By the second method three wide and two narrow benches are

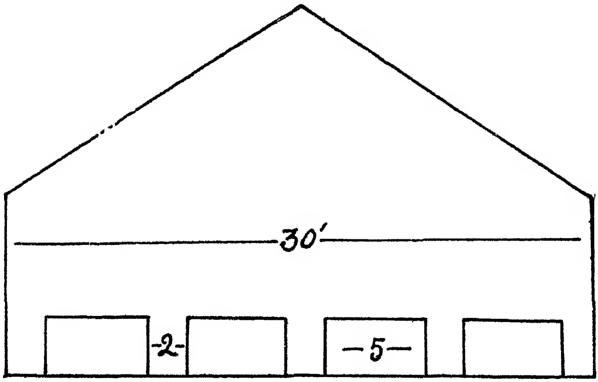


Fig. 87.—An arrangement of benches in a 30-foot house. Only 66⅔ per cent of the floor space available for crops.

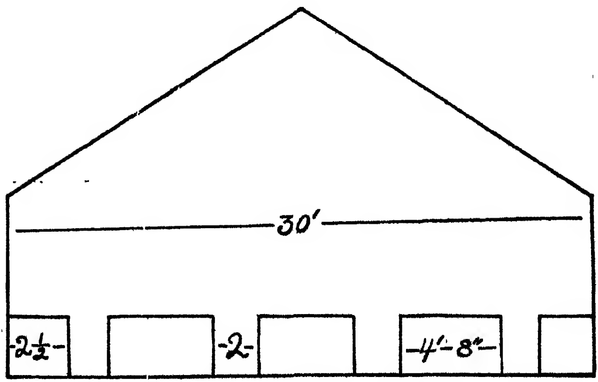


Fig. 88.—Another arrangement of benches in a 30-foot house. By this arrangement 73⅓ per cent of the floor space is available for growing crops.

provided and 73⅓ per cent of the floor space is available. In the latter method the side benches extend the entire length of the house and one walk is eliminated.

It is worth while to exercise considerable care in determining the arrangement of the benches, especially in commercial houses. As a rule a walk along the side of a house is an extravagance. When the width of the house admits, it is usually more economical to have narrow benches along each side.

When low beds are used, the walks may be narrower than the high benches as people can pass more readily. In conservatories and show houses 3 feet is none too wide. In commercial houses with high benches, from 20 to 24 inches is a common width. When low beds are used, the walks are sometimes as narrow as 14 or 16 inches.

It is often advisable to arrange the benches so as to have the center walk of extra width, which will allow of the use of a wheel barrow or cart in removing and replenishing the soil and for other purposes.

Material for Walks.—Concrete is unquestionably the best material for walks. Water has no effect on it; it is substantial; it may be used as a foundation on which bench legs and ven-

tilator columns may stand; and it may be quickly and easily laid. In conservatories and private houses nothing can take its place. For data on concrete construction see Chapter XIV. In commercial houses coal ashes are often used.

Curbs.—For convenience and cleanliness, many growers who plant directly on the ground prefer to have their houses marked off into regular beds, divided by narrow walks and surrounded by a curb to keep the soil in place. Board or plank curbs are rarely satisfactory, as the moisture of the soil on one side causes them to warp. The most satisfactory and economical curbs are made of concrete, which is heavily reinforced with iron rods when it is poured.

CHAPTER X

GREENHOUSE HEATING

Generally speaking, there are only two satisfactory methods of greenhouse heating: Steam and hot water. Direct heating by stoves is not satisfactory even in small houses, and no satisfactory system has yet been devised for the use of hot-air furnaces. The only method aside from steam or hot water which deserves mention is heating by flues. They are wasteful of fuel, and their use is not justified, except in cheaply constructed houses which are used only for a few months in the spring or fall.

The principles pertaining to greenhouse heating are much the some as those involved in heating other buildings, except that the loss of heat is greater from glass than from wood or brick walls, and a higher and more constant night temperature is required than is necessary in dwellings. For this reason, relatively more radiating surface is required and boilers of larger capacity are needed.

Heating with Flues.—In heating with flues the equipment consists simply of a furnace at

one end of the house and a chimney at the other, the two being connected by a flue, carried underneath the bench or buried just underneath the soil, through which the heat and smoke are carried. This may be made of brick, but large-size drain or sewer tile are more commonly used. These withstand the heat and are easily and cheaply put in place. It is best to have the flue slope upward slightly toward the chimney. As has already been stated, this method is wasteful of fuel. It is also difficult to regulate. It is still employed to some extent by vegetable gardeners in cheap houses, used only in late winter or early spring for the starting of early vegetable plants, sweet potatoes, etc.

Hot Water vs. Steam.—There has been much discussion as to the relative virtues of hot water and steam for use in greenhouse heating. It may be well to consider here some of the advantages claimed for each. For hot water the following are claimed: (1) It provides a more even heat than steam. (2) The radiating pipes are not so hot, and plants near them are less likely to be injured than when steam is used. (3) It requires less frequent firing, since warm water is always circulating in the pipes as long as there is any fire in the furnace, whereas, with steam it is necessary to keep the water boiling

to keep steam in the pipes. (4) For the above reason a night fireman is not required in small houses equipped with hot water. (5) It is less dangerous. This is more apparent than real, for steam is usually carried at low pressure. (6) It is claimed that hot water requires less fuel. Theoretically this should be true, but in practice it has not been very definitely proven. (7) Water will hold heat for some time if the fire should accidentally go out.

The following advantages are claimed for steam: (1) Less cost of installation. (2) Steam requires fewer radiating pipes hence less shade is cast when the pipes are placed overhead than when hot water is used. (3) Less time is required to get up heat, as there is a relatively small body of water. (4) A greater area may be warmed from a given heating plant than with hot water, for the steam may be forced farther. (5) A steam plant may be used to furnish steam for soil sterilization.

All the above apply more especially to small ranges than to large ranges. As a rule, hot water is more generally used in ranges covering up to 20,000 square feet and steam in larger ranges, although there are many exceptions. At present the tendency seems to be toward the use of hot water rather than steam.

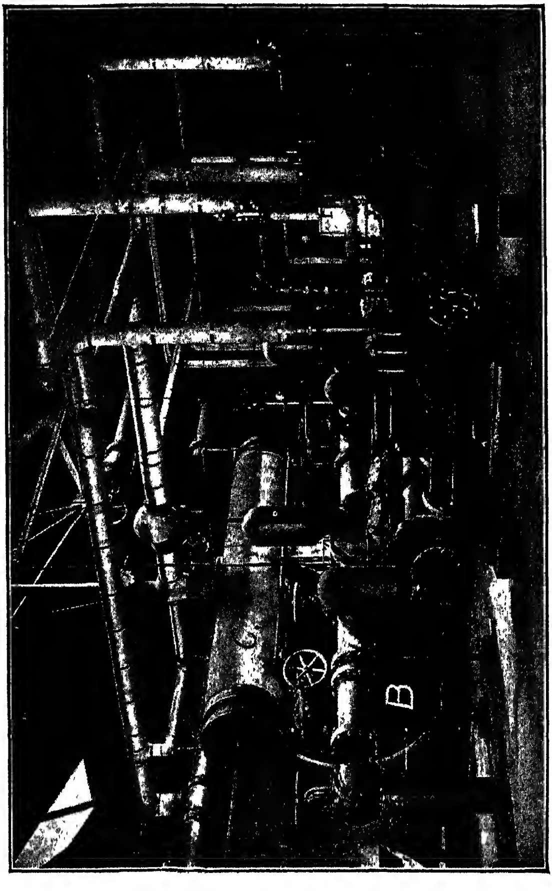


Fig. 89.—A combination steam and hot-water heating system. A, hot water boiler; B, steam boiler. Steam from B is used to pump the hot water about the range and the exhaust and superfluous steam is used to heat water in the tank C which is connected with the regular heating system.

Combination Systems.—A combination of hot water and steam may often be used to advantage. By this means steam may be had for power and at the same time be utilized for heating. In cold weather both boilers may be used for heating, while in mild weather the steam boiler alone may be used, thus furnishing the necessary heat and power.

Another and more simple combination of hot water and steam heating which, however, is more expensive in installation, consists of two separate sets of heating coils, one of which is connected with a steam boiler and the other with a hot water boiler. The steam is used when a small amount of heat is needed quickly on cold nights in early fall or late spring, and to supplement the hot water in severe winter weather.

In any system of heating it is much safer, as well as more economical in operation, to install two or more boilers rather than to depend on one large one. Both may be used in severe weather and in case of accident to one, the other may be forced for a few days and thus protect the plants from injury by freezing, which would inevitably result if only one boiler was in use.

Heating Coils.—Because of the large amount of heating surface required, and because all parts of a greenhouse must be kept at as nearly uniform temperature as possible, radiators such as are used in private houses have not been found practicable in greenhouse heating. Instead, long coils of wrought iron or steel pipe are used. For steam heating these coils are commonly of 1 or 1¼-inch pipe. In hot water heating they are slightly larger, varying from 1¼ to 2 inches. In the early days of hot water heating large cast-iron pipe, often as large as four or five inches in diameter was used. It is still used to some extent, but more often in small private conservatories than in commercial houses.

There is very little to be said in favor of using cast-iron pipes. The fact that they are now so little used shows that they have no special merit. The smaller, wrought pipe is lighter and much more easily handled; is screwed together instead of caulked with lead and oakum; has much more radiating surface in proportion to the volume of water contained; can be placed along the side walls or hung on the supporting posts instead of having to be supported on masonry piers; and permits of a more perfect control of the heat.

Heating coils are made by joining several pipes together by means of headers. The hot

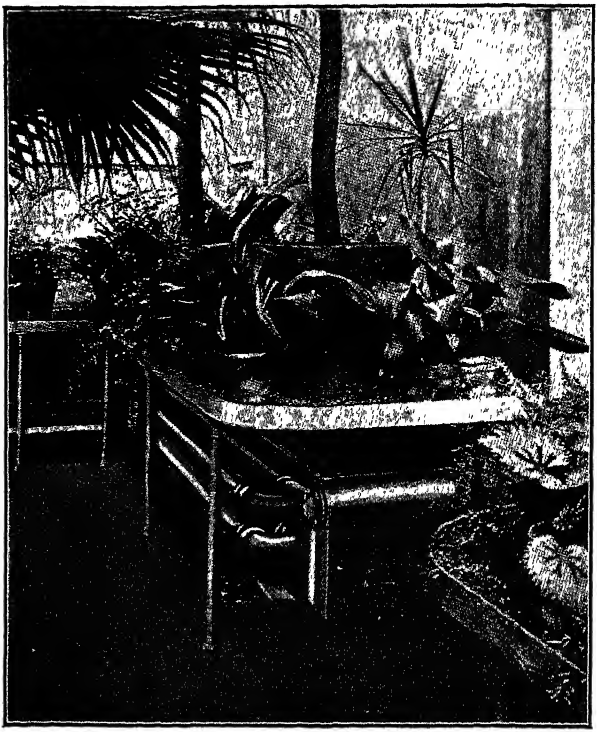


Fig. 90—Under-bench heating with large cast-iron pipes.

water is conducted to the coils from the boiler by means of a larger pipe known as a flow pipe or feed pipe. It is returned to the boiler

by means of a return pipe. In steam heating the coils are often so arranged that the water formed from the condensed steam returns to the boiler through the flow or feed pipe, instead of through a separate return pipe.

CHAPTER XI

HOT WATER INSTALLATION

General Principles.—Before discussing the installation of a hot water heating system it is necessary to have in mind the physical and mechanical principles involved. Briefly they are these: Water increases in volume as it is heated and it is consequently lighter in weight. When a fire is lighted under a water boiler the water around the heating surface expands and, being lighter, is forced upward by the heavier, colder water. Popularly speaking, the hot water "rises."

The practical problem is to conduct the hot water from the boiler to the coils where the large radiating surface permits the water to give up its heat to the air in the house and then, as it becomes colder and heavier, to conduct it back to the boiler where it will displace the warmer and lighter water there. Gravity is the force utilized to produce circulation. It acts with a force proportional to the difference in weight between the column of warm water and the column of cool water.

The following table shows the weight of a cubic foot of distilled water at different temperatures.

32	degrees F	...62.42	pounds	170	degrees F	...60.77	pounds
100	"	....62.02	"	180	"	....60.55	"
110	"	....61.89	"	190	"	....60.32	"
120	"	....61.74	"	200	"	....60.07	"
130	"	....61.56	"	210	"	....59.82	"
140	"	....61.37	"	220	"	....59.76	"
150	"	....61.18	"	230	"	....59.37	"
160	"	....60.98	"				

From the above table it is apparent that a cubic foot of water entering the boiler at 140 degrees is 0.82 pounds heavier than an equal quantity leaving the boiler at 180 degrees. It is evident that the higher the columns of water the greater will be the difference in weight, and consequently the more rapid will be the flow.

The various factors influencing the velocity of water in a gravity hot water system are embodied in the following formula.

$$V = \sqrt{\frac{2gh\,(w - W)}{(w + W)}}$$

In this formula, V = the velocity in feet per second, g = the force of gravity (32.16), h = the total height of the system, W = the weight of a cubic foot of water when it leaves the boiler and w = the weight of a cubic foot of water when it enters the boiler.

This, of course, disregards friction. The practical application is that when it is desired to increase the velocity of the water; e.g. in long runs, it may be done by either lowering the boiler or by raising the height of the flow pipes.

The following table shows the velocity in feet per second in a hot water system under various conditions.

Height of Column	Difference in temperature on leaving and entering boiler					
	5°	10°	15°	20°	30°	40°
	Feet per second					
5 ft.	0.541	0.750	0.922	1.09	1.33	1.51
10 "	0.765	1.06	1.32	1.55	1.88	2.04
20 "	1.085	1.50	1.85	2.19	2.66	3.01
30 "	1.35	1.83	2.26	2.68	3.26	3.71

Arrangement of Piping.—There are two approved methods of arranging the piping for hot-water heating. One is known as the "down hill"; the other as the "up hill." In the former the highest point in the system is directly above the boiler. In the latter the highest point is at the end of the system farthest from the boiler. Either is satisfactory and is preferred to the "level" system sometimes advocated. In either the "down hill" or the "up hill" system the air which collects in the pipes will eventually reach the highest point when it may be allowed to escape through an automatic air valve. In the

"level" system slight sags and raises are likely to occur and the air will collect in the higher parts and cause trouble.

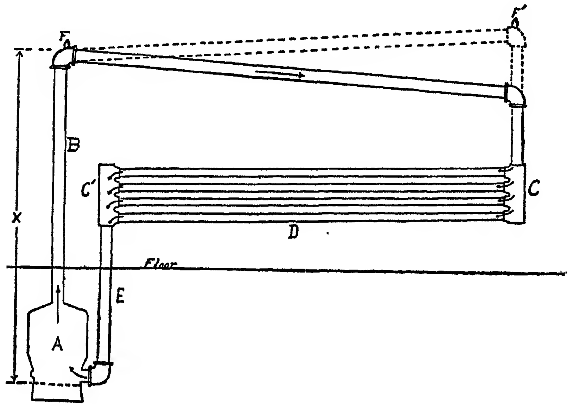


Fig. 91.—Diagram showing "down-hill" and "up-hill systems of piping. A, boiler; B, flow pipe; C, C', headers; D, radiating pipes or coils; E, return pipe; F, automatic air value; X indicates height of water column.

The author prefers the "down hill" system when the flow pipes are carried in the upper part of the house and the coils are considerably lower. When all the pipes must be in the lower part of the house, or under the benches, he prefers the "up hill" system. The majority of greenhouse operators seem to be in accord with this view. Practically speaking there appears to be but little difference in the efficiency of the two systems and the convenience and the ar-

rangement of the house determines the choice to a considerable extent.

Estimating Radiation.—The calculations for greenhouse heating are based on certain fundamental facts which for hot water may be stated briefly as follows: A square foot of glass will give off, under ordinary greenhouse conditions in winter weather, approximately 1 B. T. U.* of heat per hour, for each degree difference in temperature between the air inside the greenhouse and that outside. A good wood, brick or concrete wall will give off about a sixth as much, or a sixth B. T. U. per square foot per hour. It is customary to divide the total wall surface by six and consider it as equivalent to glass.

To arrive at an estimate of the possible heat loss from a greenhouse add to the total square feet of exposed glass surface a sixth of the total square feet of exposed wall surface, and multiply the sum by the difference between the temperature at which the house is to be kept and the lowest outside temperature which will probably be experienced. Suppose, for example, that a house has 10,000 square feet of glass and equivalent glass, that it is desired

* British Thermal Unit; the amount of heat required to raise one pound of distilled water from 62 to 63 degrees F.

to keep it at a night temperature of 50 degrees, and that the lowest outside night temperature to be expected is —10 degrees. The number of B. T. U. given off by such a house under these conditions would be [50°— (—10°)] x 1 x 10 x 10,000 or 600,000 B. T. U., and enough heating coils must be provided to supply this amount.

In hot water heating the coils will give off approximately two B. T. U. per square foot of surface per hour for every degree difference in temperature between that of the coil and that of the surrounding air. The average temperature of the coils may be taken to be 160 degrees, and if the house is to be maintained at 50 degrees the difference will be 110 degrees. Multiplying 110 by 2 we have 220 or the number of B. T. U. given off by each square foot of radiating surface per hour. If, then, we divide 600,000 by 220 we have 2,727 which is the number of square feet of radiating surface to be provided for 10,000 square feet of glass.

These principles may be embodied in the following formula where R = the amount of radiating surface required in square feet; T, the temperature to be maintained inside the house; t, the lowest outside temperature to be ex-

pected; and G, the number of square feet of glass and equivalent glass.

$$R = \frac{(T\text{-}t) \times G}{(160\text{-}T)\,2}$$

This formula gives a wide margin of safety. Most builders prefer to use considerably less radiating surface and depend on forcing the furnace in extremely cold weather. By so doing the temperature of the coils may be kept at 180 degrees or even considerably higher under favorable conditions and the amount of radiation required will be correspondingly less.

Amount of Pipe Required.—Having estimated the amount of radiation required the next problem is to find the quantity of pipe necessary to provide this amount. For example, 1 linear foot of 1½-inch pipe furnishes about half a square foot of radiating surface. Divide the number of square feet of radiation required by the outside area of a linear foot of pipe of the desired size. The result will be the number of linear feet of pipe required. From this is subtracted the amount of radiation supplied by the flow or feed pipe and other fittings.

The following table gives the radiating area in square feet of a linear foot of pipe of various sizes.

Size of pipe	Radiating surface of 1 linear foot
¾ inch	0.27 square feet
1 "	0.35 " "
1¼ "	0.43 " "
1½ "	0.49 " "
2 "	0.62 " "
2½ "	0.75 " "
3 "	0.91 " "
3½ "	1.05 " "
4 "	1.18 " "

For practical purposes the following general rule will give approximately the amount of radiating surface required. Divide the number of square feet of glass and equivalent glass:

By 6 to heat the house to 40 degrees
By 4 to heat the house to 50 degrees
By 3.5 to heat the house to 60 degrees
By 3 to heat the house to 70 degrees

The quotient will be the surface feet of radiating surface required.

Size of Flow Pipe.—Having determined the amount of radiation necessary, the next problem is to determine the size of the flow or feed pipe required to supply the coils. Experience has shown that it is not necessary for the supply pipe to be equal in capacity to the sum of the capacities of the coil pipes. The correct size may be determined, theoretically, by the use of the following rather tedious formula:

$$A = \frac{H\ R}{25wvt}$$

In this formula A = the cross section area in square inches of the flow pipe; H, the total radiation in B. T. U. per hour given off by the coils; R, the radiating surface in square feet; w, the weight of the water per cubic foot; v, the velocity of feet per second; t, the difference in temperature between the water when it leaves the boiler and when it returns.

This formula is seldom used but the following table has been derived from it. To use, measure the height of the water column in feet, find from the table the factor for this height, and multiply the square root of the radiating surface in square feet by this factor. The result will be the size of the flow pipe, in inches (diameter) required. This is based on the assumption that there is a difference of 10 degrees in temperature between the water when it leaves and when it enters the boiler.

Height of Column (ft.)	Diameter Factor
5	0.133
10	0.113
15	0.104
20	0.095
25	0.091
30	0.187

For example, to supply a coil of ten 1½-inch pipes 100 feet long (500 square feet) 15 feet above the bottom of the boiler, would require

a feed pipe the diameter of which would be represented by $\sqrt{500} \times 0.104$ equals 22.4×0.104 equals 2.33 or a 2½-inch pipe.

Short Methods.—The above formula takes into consideration the fact that the greater the height of the column of water the more rapid the flow and consequently the smaller may be the supply pipe used. In greenhouse heating, however, the height is seldom very great, usually varying between 8 and 20 feet, so that the following rule of thumb usually proves satisfactory. The flow pipe should be one pipe size greater in diameter (inches) than the square root of the radiating surface of the coil (in square feet), divided by 10. Applying this rule to the above problem we have $\sqrt{500} \div 10 = 2.24$. The next pipe size is 2¼ inches but this is so close to the estimated size that a 2½-inch pipe should be used to insure efficiency.

The size of the main supply pipe from the heater is determined in the same manner by taking the sum of all the radiating surface to be supplied. It is better to have one main flow pipe leading from the boiler, from which branches to the various coils may be taken, than to have a flow pipe direct from the boiler for each coil, though two or more flow pipes may be taken off. The return pipes should be

of the same size as the flow pipes. The flow pipe is taken from the top of the boiler and the return pipe enters at the bottom.

In Fig. 92 is shown a diagram of a method for piping a medium-sized house. In the diagram A is the flow pipe extending directly up

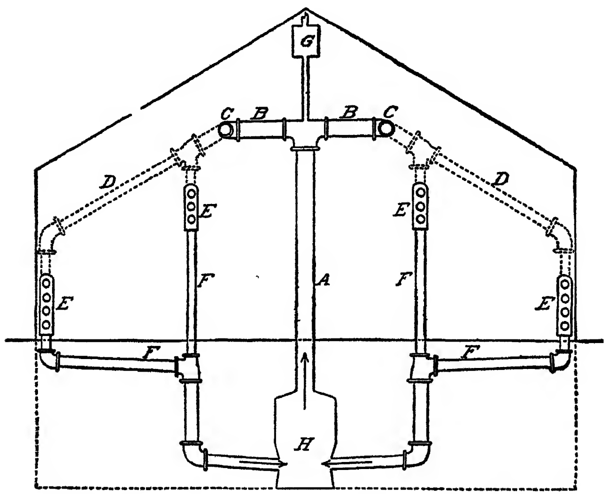


Fig. 92.—A method of piping a medium size house.

from the boiler; B, B, branch flow pipes; C, C, branch flow pipes extending the length of the house; D, D, distributing pipes at the opposite end of the house; E, E, E, E, the return coils; F, F, F, F, return pipes; and G, expansion tank.

Valves should be conveniently placed so that

any or all of the coils may be cut off individually. They may be placed either in the flow or return pipe, or in both. If there is a valve in both the supply and return from each coil, any one may be repaired in case of an accident without drawing the fire or interfering with the circulation in the other coils. The valves should be of a type which, when open, cause little resistance to the flow of water.

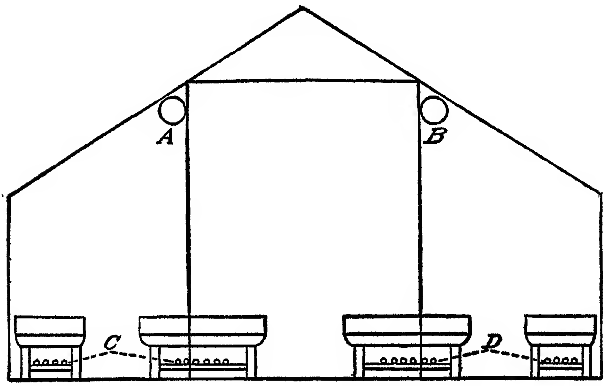


Fig. 93.—Diagram showing under-bench method of hot water piping. A and B flow pipes; C and D heating coils.

Length of Coils.—The length of the coils which may be used depends: (1) Upon the height of the column of water; (2) upon the size of the pipes which make up the coils; and (3) the amount of friction in the coils and fit-

tings. The length of coils which may be satisfactorily used with pipes of various sizes are given in the following table.

Size of pipe	Length of coil
1 inch	Up to 50 feet
1¼ inch	50 to 75 feet
1½ inch	75 to 100 feet
2 inch	100 to 150 feet

This table is based on the supposition that gravity, only, is to be depended upon for circulation. When pumps are used to circulate the water the length may be materially increased.

The most commonly used size is 1½-inch, and when the houses are much over 100 feet in length two or more coils may be used, each extending only a part of the length, and having separate feed and return pipes.

Expansion Tank.—Water expands in heating. It is necessary, therefore, to make some provision to take care of the expansion, in order that the pipes shall not burst and to keep them full at all temperatures. This is accomplished by connecting the system with an expansion tank into which the excess water will flow as it expands, and from which it will flow back into the system as it cools. It is placed at or above the highest point in the system, but it may be connected with any part of the system or even with the boiler.

The size of tank required is directly proportional to the volume of water contained in the system and is determined by the amount of ex-

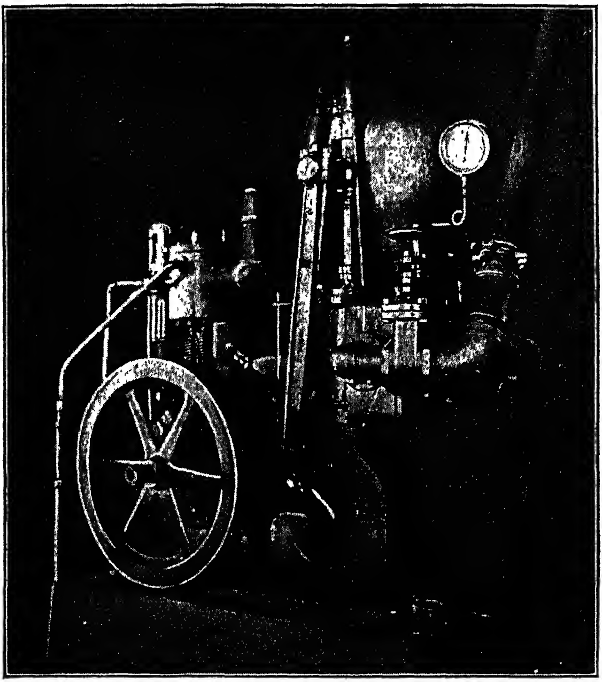


Fig. 94.—Gasoline engine arranged to circulate hot water in a greenhouse heating system.

pansion resulting from heating. The following table adapted from Kent shows the relative amount of expansion.

Temperature Cent.	Temperature Fahr.	Comparative Volume
4°	39.1°	1.00000
10°	50. °	1.00025
20°	68. °	1.00171
30°	86. °	1.00425
40°	104. °	1.00767
50°	122. °	1.01186
60°	140. °	1.01678
70°	158. °	1.02241
80°	176. °	1.02872
90°	194. °	1.03570
100°	212. °	1.04332

From the above table it will be seen that the increase in volume from 50 to 212 degrees is 1.04432—1.00025=0.04307, or a little more than 4 per cent. It is customary to make the

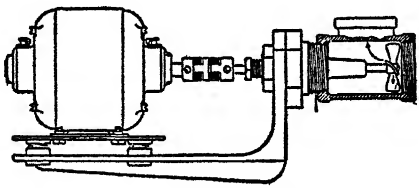


Fig. 95.—An electrically driven turbine for circulating hot water. The turbine may be installed in an elbow or T of either the flow or return pipe.

expansion tank large enough to hold 5 per cent. or a twentieth of the water contained in the system, including the boiler. Thus, if the system contains 100 gallons, the supply tank should be large enough to hold a twentieth of that amount or 5 gallons.

The capacity in gallons of a linear foot of standard wrought pipe is shown in the following table.

Size of pipe diam. in inches	Capacity per linear foot
1	0.1408 gallons
1¼	0.0638 "
1½	0.0918 "
2	0.1632 "
2½	0.2550 "
3	0.3672 "
4	0.6528 "
5	1.0200 "
6	1.4690 "

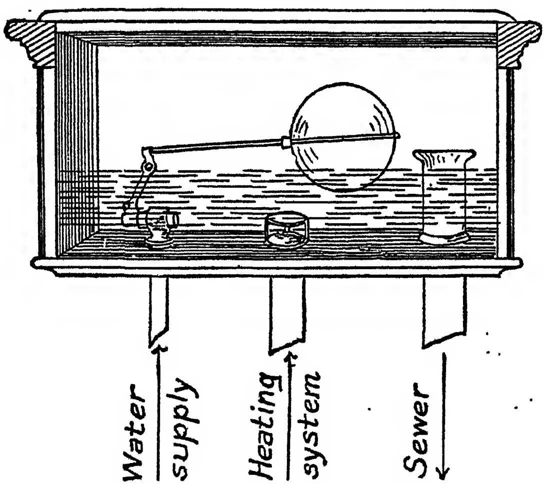


Fig. 96.—Automatic expansion tank. This is connected with the city water system and will automatically keep the heating system filled See also G, Fig. 92..

Pressure Systems.—Water in an open kettle cannot be heated above 212 degrees at sea level. At that temperature it boils and all further heat energy is expended in vaporizing the water. In an open hot-water heating system the same is true, except that the slight pressure of the column of water in the system may permit the water in the boiler to reach a temperature slightly above 212 degrees. If water can be kept under pressure it may be raised to almost any desired temperature, and in a heating system this would mean less necessary radiating surface. The boiling point of water under various pressures above normal or atmospheric pressures is shown in the following table:

Pound pressure	Boiling point
Normal	212.0° Fahr.
½ pound	213.7° "
1 "	215.3° "
2 "	218.5° "
3 "	221.5° "
4 "	224.4° "
5 "	227.1° "
6 "	229.7° "
10 "	240.0° "

Several systems have been evolved to produce pressure in a heating system. One of the earliest was the closed tank system in which the expansion tank was made air-tight and fitted with a safety valve set so as to let the air in the

tank escape at a certain pressure. By this means the water in the coils may be made to reach a temperature considerably above the boiling point.

Various automatic devices using a column of mercury to produce the same result have been placed on the market. One model is designed to be placed in the pipe leading from the return pipe to the expansion tank, the tank in this case being open. The advantage of these devices over the closed tank system lies in the fact that they are less likely to become clogged and stick than are the safety or pop valves.

When the hot water is circulated by pumps it is possible, though probably not desirable to maintain a high pressure. Economy in heating by hot water lies in having abundant radiating surface and rapid circulation and then keeping the water at a moderate temperature.

Caution.—In any system see that the expansion tank and the pipe leading to it are placed where they will not freeze. As there is ordinarily no circulation in the water they contain they will freeze if placed where the temperature falls below freezing. The results will almost surely be disastrous.

CHAPTER XII

STEAM INSTALLATION *

General Principles.—In steam heating there is no circulation in the same sense that there is in hot water heating, but the steam is conducted into the heating coils, where it condenses. In condensing it gives up its "latent" heat. The water of condensation, which occupies only about 0.017 part of the space occupied by the steam, finds its way back to the boiler either by flowing back through the supply pipes, or through return pipes connected with the opposite ends of the coils. The latter system is most commonly used in greenhouse heating.

In contrasting steam and hot-water heating it is well to keep in mind the fact that only 180 B. T. U. are required to raise one pound of water from 32 to 212 degrees but that 966 B. T. U. (usually considered as 1000) are re-

* In order to avoid repetition steam heating is discussed largely in contrast to hot water heating, as described in the preceding chapter. Both chapters should be read by one wishing to inform himself on steam heating.

quired to change a pound of water at 212 degrees into steam. When the steam is condensed in the coils it gives off this heat. This is known as the latent heat of steam. It may be defined as the amount of heat absorbed in changing from a liquid to a vapor or the amount given off in changing from a vapor to a liquid state.

The problem in steam heating is to supply an amount of radiating surface sufficient to condense enough steam to furnish the amount of heat required. Under ordinary greenhouse conditions a square foot of steam radiating surface may be counted on to condense approximately one quarter pound of steam per hour. Each square foot of radiating surface will, therefore, provide a fourth of 966 or approximately 240 B. T. U. per hour.

The number of B. T. U. required per hour to heat a given house (see page 172), divided by 240 will give the number of square feet of steam radiation required, and from the table on page 175 the number of linear feet of pipe may be easily determined. Assuming a steam pressure of five pounds per square inch the following rule will be found useful in determining the amount of steam radiation required for a house when the lowest outside temperature to be expected is not lower than zero.

Divide the number of square feet of glass and equivalent glass.

By 9 to heat house to 40 degrees
By 7 to heat house to 50 degrees
By 6 to heat house to 60 degrees
By 5 to heat house to 70 degrees

The quotient will be the number of square feet of radiating surface required.

Size and Length of Coils.—There is less friction in steam than in hot-water heating, and for this reason smaller pipes may be used in the heating coils. They are seldom larger than 1½-inch, and 1¼-inch is very commonly used. Even 1-inch pipe may be used in comparatively short runs. Smaller supply pipes may also be used in steam than in hot-water heating, for the reason that the radiation per square foot of surface is greater and therefore less surface is required. In other words, an equal number of smaller pipes or a smaller number of pipes of equal size may be used in steam than in hot-water heating. Small pipes furnish a greater amount of radiation in comparison to their cubic capacity than do large pipes. Large cast-iron pipes are almost never used in steam heating.

When 1-inch pipe is employed coils may be safely used up to 75 feet in length; 1¼-inch

up to 150 feet; and 1½-inch up to 250 feet. As with hot water, better results and a more uniform temperature may be obtained by using two or more comparatively short coils, rather than one which is excessively long. In small houses it is possible to run the coils entirely around the house, maintaining an even downward slope.

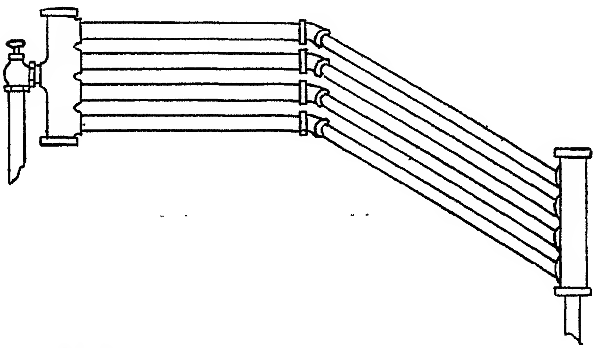


Fig. 97.—A corner coil. It allows for expansion of the pipes.

Arrangement of Coils.—As indicated in a preceding paragraph, either of two methods of piping may be used. In one the water resulting from the condensation of the steam flows back to the boiler through the supply pipe. In this case all pipes have an upward slope from the boiler, with no sags or pockets in which the water can collect. This method, sometimes

known as the single pipe system, is very commonly used in heating dwellings where the pipes are mostly vertical, but in greenhouses having long, nearly horizontal coils there is likely to be much hammering in the pipes, caused by the interference of the steam with the return water.

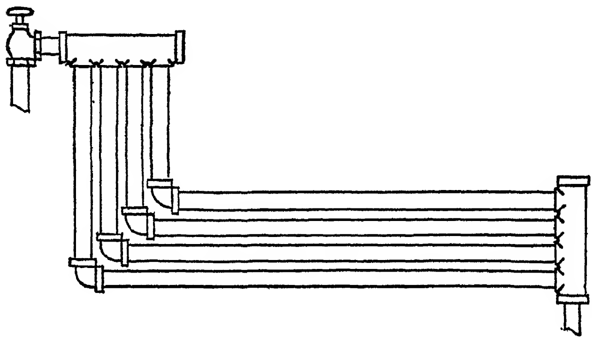


Fig. 98.—A mortise coil designed to allow for expansion of pipes.

A more satisfactory method for greenhouse heating is to arrange the pipes much the same as in hot-water heating, proportioning the size to the supply and return pipes according to directions given in a following paragraph. This is known as the two-pipe system. The return pipe enters the boiler below the surface of the water. The coils should have a fall toward the boiler of about 1 inch to 20 feet. It is not wise to use the straight coils commonly used for hot

water in steam heating as they do not allow for the unequal expansion of the pipes when the steam is turned on quickly. In steam heating special forms of coils are commonly used among which are the corner coil and mortise coil.

The increase in length of wrought-iron pipe caused by expansion by heating is shown in the following table.

Temp. of pipe when fitted	Increase in length of 100 feet of pipe in inches when heated to				
	160°	180°	200°	212°	220°
32°	1.02 in.	1.18 in.	1.34 in.	1.44 in.	1.50 in.
50°	.88 "	1.04 "	1.20 "	1.30 "	1.36 "
70°	.72 "	.88 "	1.04 "	1.14 "	1.20 "

Size of Supply and Return Pipes.—Theoretically, the size of the flow and return pipes in steam heating may be much smaller than in hot-water heating. This is especially true of the return pipe, since the water which it carries occupies only 0.017 of the space occupied by the steam from which it is condensed. In practice, however, the flow or supply pipe for steam is made nearly as large as for hot water and the return pipe only slightly smaller.

The following table shows the flow of steam in pipes of different sizes at a pressure at the boiler of approximately five pounds.

Size of pipe	Pounds of steam per hour
1½ inches	70
2 "	138
2½ "	220
3 "	390
3½ "	570
4 "	800
4½ "	1000
5 "	1400
6 "	2200
7 "	3200

To find the size of supply pipe required it is only necessary to determine the number of pounds of steam condensed per hour by the coils (approximately one-quarter pound for every square foot of radiation) and from the above table select the correct size.

The following table, adapted from Carpenter, gives the size of supply and return pipes recommended to be used in the two-pipe system for different amounts of radiation, when a pressure of not greater than five pounds is used.

Sq. ft. of radiation to be supplied	Size of supply pipe	Size return pipe
200	1½ inch	1¼ inch
400	2 "	1½ "
700	2½ "	2 "
1000	3 "	2 "
1600	3½ "	2½ "
2300	4 "	2½ "
3200	4½ "	2½ "
4100	5 "	3 "
6500	6 "	2 "
9500	7 "	3½ "

Valves.—In steam heating it is essential that each coil be provided with a cut-off valve. This is even more essential than with hot water since with steam heating the temperature of the steam must be at least 212 degrees, while with hot water the temperature may be varied ac-

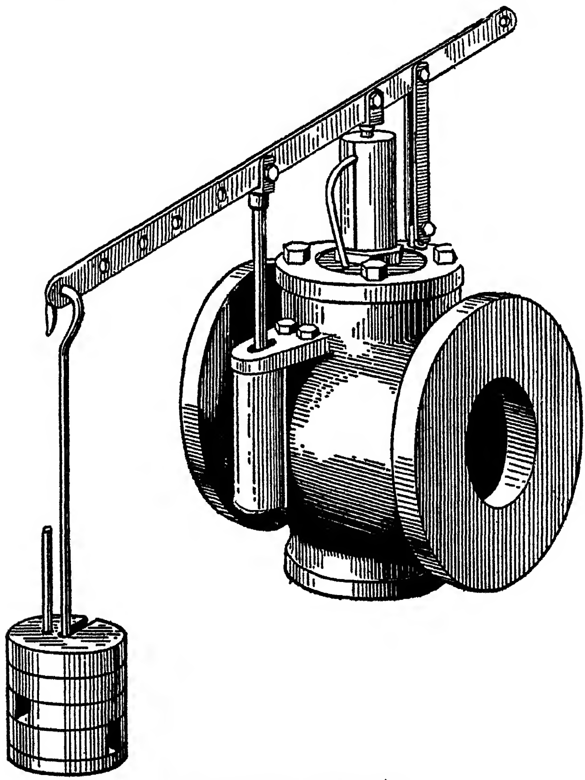


Fig. 99.—Reducing valve.

cording to the weather. Automatic air valves are placed at the highest point of each coil and also in the supply pipes.

High Pressure Heating.—When steam above five pounds pressure is used it is known as high pressure heating. For greenhouse purposes high pressure heating is not satisfactory, as the pipes are too hot. In large establishments, however, a high pressure is often maintained at the boiler and is passed through a reducing valve before it enters the coils.

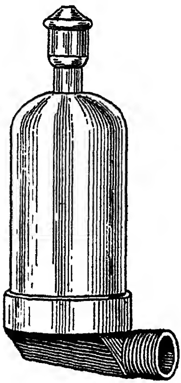


Fig. 100.—A type of automatic air valve.

Vacuum and Vapor Systems.—Several heating systems are now on the market which endeavor to give to steam heating some of the advantages claimed for hot water, viz., a lower temperature of the heating pipes and less frequent attention to the boiler. They differ from straight steam heating in that a partial vacuum is maintained within the system, thus causing the water in the boiler to give off vapor at a temperature of less than 212 degrees.

There are several different systems but they may all be grouped roughly into three classes:

(1) Those in which a vacuum is created by means of a pump or other mechanical device; (2) those in which the air is expelled by raising the steam to a relatively high pressure, and then preventing it from returning by some form of automatic mercury seal, and (3) those in which a constant, though slight, vacuum or tendency to vacuum is maintained, by connecting the system with the chimney and utilizing the "pull" of the draft. In addition to the advantages given above it is claimed for these systems that they are more economical of fuel than are either steam or hot water, that the circulation is better and surer, and also that there is no trouble arising in long runs from water of condensation.

Arrangement of Boilers.—In the common gravity system of steam heating the boilers must be below the level of all mains and coils. When they cannot be so located, special devices to be described later must be employed to return the water of condensation. As with hot water, two or more boilers should be provided, rather than one large one, to allow for repairs in case of accident and for use in severe weather to avoid the necessity of forcing.

Steam Pumps and Traps.—As suggested in the preceding paragraph, it is sometimes impos-

sible or inconvenient to place the boilers below the level of the heating coils. This is especially true in large establishments, requiring large boilers using large quantities of fuel. In order to return the water of condensation in such cases steam return traps and steam pumps are used. Their use is also necessary where a higher pressure is carried at the boiler than in the coils.

The return trap is a contrivance which is automatic in its action, and which overcomes the back pressure from the boiler by an ingenious method of equalizing the difference in pressure between the boiler and the coils. Being automatic in its action and requiring but little attention it has been quite generally used. Steam pumps, on the other hand, require considerable attention, though they are less complicated than the return traps.

Steam for Soil Sterilization.—Crops grown in hotbeds and greenhouses are often attacked by nematodes or by wilts and other diseases the producing organisms of which live in the soil. To control them it is necessary to sterilize the soil. A common method is to kill the organisms by heating the soil, usually with steam. To be effective they must be heated for at least an hour at a temperature of 182 degrees.

Steam sterilization is best accomplished by laying lines of tile permanently in the soil 18 inches apart, deep enough so they will not interfere with cultivation, and into which live steam is conducted. Either high or low pressure steam may be used but since it takes about three and one-half times as long to treat a given area with steam at a pressure of 10 pounds as it does at 80 pounds, high pressure is more economical of time and is usually preferred. Pressures of less than 10 pounds are not effective except in small areas. It also requires about 20 times as much steam (B. T. U.) to heat a given area of soil to 182 degrees for an hour as it does to maintain a growing temperature for the same area for the same length of time.

If steam is normally carried at a high pressure in the heating boiler it may be led direct to the sterilizing pipes. If the boiler is run to capacity and a pressure of 80 pounds is maintained about one twentieth of the houses may be treated at one time, one and one half to two hours being required for each section. Thus it will be necessary to lay the pipe lines in sections of approximately one-twentieth of the soil surface area if the job is to be done economically or to provide some supplementary source of steam.

When hot water, electricity or flues are used for heating a portable boiler such as is used to provide power for threshing may be used with good results. A rough estimate of the capacity of a high pressure boiler for use in soil sterilization may be made by allowing 10 square feet of soil surface area to each boiler horsepower and allowing from one to two hours to sterilize each unit area. A thermometer should always be used to check the soil temperature making sure that the far end of the bed reaches the desired temperature.

Wet soils require more steam to heat to sterilizing temperature than do dry soils. Covering the soil with straw or sash bed mats will help to prevent radiation of heat and materially aid in keeping up the temperature.

CHAPTER XIII

BOILERS, FUELS AND FLUES

The term boiler and heater as used in discussing greenhouse heating systems are synonymous. It is customary, however, to speak of a steam heating apparatus as a "boiler" and of a hot-water heating apparatus as a "heater," probably because in steam heating the water boils, while in hot-water heating it is not supposed to boil. It often occurs, however, that the same kind of heating apparatus is used in both steam and hot-water heating with no essential changes, except in the accessories. In this chapter the term boiler will be applied to both steam and hot-water heating devices.

The boilers used in greenhouse heating differ but little from those used in heating other buildings. In fact the same makes and styles of boilers are very frequently used for both purposes. Certain manufacturers have, however, made a thorough study of greenhouse heating and have developed boilers with this particular end in view. In buying a boiler the safe plan is

to purchase a style which has fully established itself on the market and which is made by a thoroughly reliable firm. Such boilers will have passed the experimental stage and repairs may be obtained quickly and reasonably.

Essentials of a Boiler.—The function of the boiler is to extract the latent heat from the fuel and transfer it to the water or steam, which may be circulated where needed. The essentials are, a grate on which the fuel is burned and a watertight receptacle, so arranged as to present a large amount of surface (known as fire surface) to the fire or burning gases. The problem of the manufacturer is to so arrange and proportion the fire surface and the grate surface that the heat of the burning fuel may be most economically absorbed and distributed.

Grate Surface.—For best results the amount of grate surface should be large enough, so that the fire will not have to be forced. In small and medium-size boilers the rate of combustion should not exceed from five to seven pounds of coal per square foot or grate per hour. In larger boilers the rate of combustion of fuel may be as high as from six to ten pounds per square foot per hour.

A pound of best coal has a heating value of about 14,000 B. T. U. per pound, of which only

about 60 per cent. or 8,400 B. T. U. are utilized in heating water or producing steam. It is the usual practice to estimate that each pound of coal will impart about 8,000 B. T. U. to the heating medium, and that each square foot of grate surface will burn about six pounds of coal per hour. This gives 48,000 B. T. U. per square foot of grate surface per hour.

To find the approximate number of square feet of grate surface required to heat a given house, find the number of heat units required, by the method described in Chapter XI, and divide by 48,000.

In general, a square foot of grate surface is sufficient to supply 250 square feet of radiating surface.

Fire Surface.—Fire surface (sometimes known as heating surface or water surface) is of two kinds; direct and indirect. The direct fire surface is that immediately above or around the fire, against which the light of the burning fuel shines. Indirect fire surface is that which receives the heat from the burning gases on their way to the chimney. Direct fire surface is three times as effective as indirect. It does not follow, however, that boilers having the greatest amount of direct fire surface are the most efficient, for there must be sufficient length

of fire travel to consume the gases and enable them to give up the greater part of the heat of combustion to the water.

To be most effective the fire surface is so arranged that the heat will impinge at right angles against it. This is accomplished without serious interference with the draft, and without making the course of the water in the boiler so long and tortuous as to interfere with its rapid circulation. The proportion of fire surface to grate surface differs so widely in the different forms of boiler construction that no definite rule can be given. It may vary from 15 to 35 square feet to each square foot of grate area.

Types of Boilers.—Broadly speaking, there are three types of boilers, when classified as to their form of construction: (1) Boilers in which the water is spread out in thin sheets between layers of iron or steel and against which the heat strikes; (2) tubular boilers in which the burning gases travel through tubes or flues which are surrounded by water; and (3) water-tube boilers in which the water is contained in tubes about which the burning gases circulate. Many manufacturers combine two, and sometimes all, of the above types in one boiler. The latter two types are more com-

monly used for power purposes than is the first, but for heating establishments of moderate size a modification of the first is widely used.

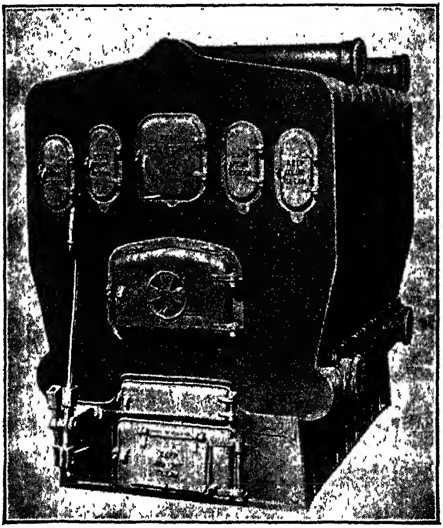


Fig. 101.—A type of "vertical" or "square" sectional boiler.

Cast and Wrought-Iron Boilers.—The cast-iron boiler has a size limit above which it is impracticable to go, though two or more may be joined in a series. It is also claimed that on account of the thickness of the walls it is less economical of fuel than are wrought-iron boilers, which have thinner walls. On the other

hand, cast-iron boilers do not rust as badly as wrought-iron ones when not in use, and they have no flues to be burned out by the sulphurous

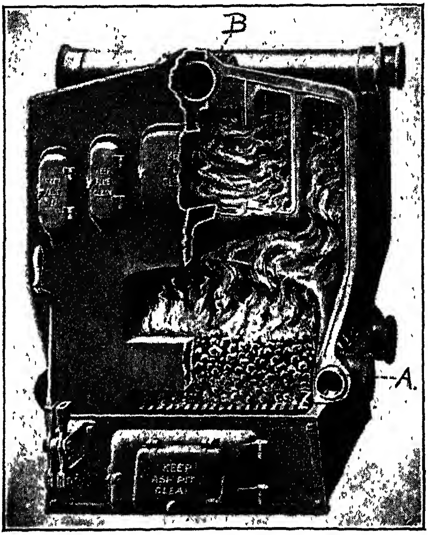


Fig. 102.—End view of "square" sectional boiler showing fire travel. A and B, push nipples for joining sections.

gases resulting from the use of the poorer grades of coal. But they do sometimes crack, and they have a disgusting way of doing it at the most inopportune moment.

Where fuel is cheap and abundant, and especially in small ranges, or where the boiler

is in a damp basement and likely to be neglected during the summer, cast-iron boilers are likely to give better satisfaction than wrought-iron. In large establishments of 100,000 feet or over,

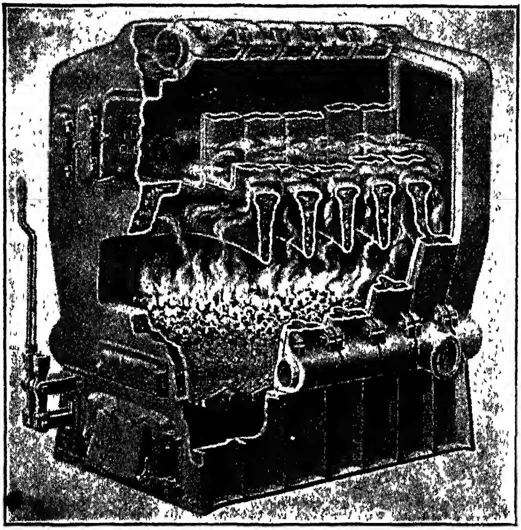


Fig. 103.—Side view of "square" sectional boiler showing fire travel.

large wrought-iron tubular or water-tube boilers are almost always used.

Styles of Cast-Iron Boilers.—There are three general types or styles of cast-iron boilers. The most popular is the "vertical" or "square" sectional boiler. (Fig. 101). The advantages

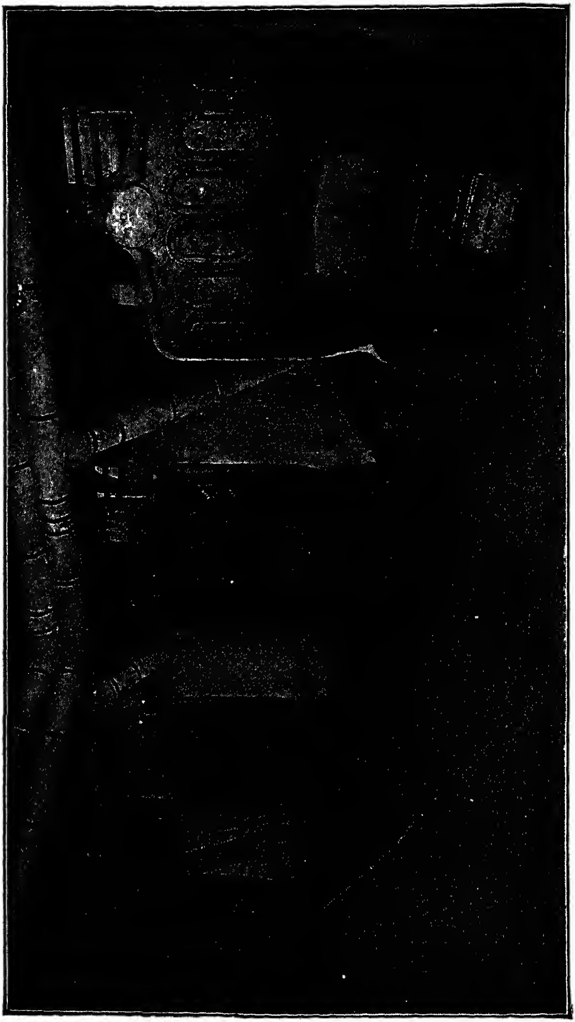


Fig. 104.—Battery of five cast-iron sectional boilers.

claimed for these forms of boilers are: (1) They may be enlarged by adding extra sections; (2) a break or crack will usually be confined to one section; and (3) they may be made in large sizes because the individual castings are comparatively small and light.

The sections are joined together by accurately ground push nipples or by screw nipples. Probably 80 per cent. of the cast-iron boilers now being placed in greenhouses of moderate size are of this general type.

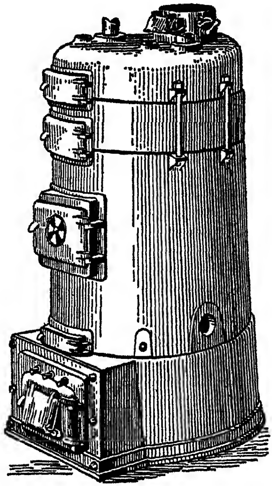


Fig. 105.—A type of "round" or "horizontal" sectional boiler.

A second style of cast-iron boiler is known as "horizontal" or "round" sectional boiler. (Fig. 105). It gives good satisfaction in small ranges but is not made in large sizes. In a third style there are no sections, but the boiler proper is cast in one piece. For this reason its size is limited. It is also open to the disadvantage that a crack will spoil the whole boiler. It is little used at present.

Types of Wrought-Iron Boilers.—Most of the larger types of wrought-iron boilers are of either fire-tube or water-tube construction. In the former the heated gases pass through tubes which are surrounded with water. In the

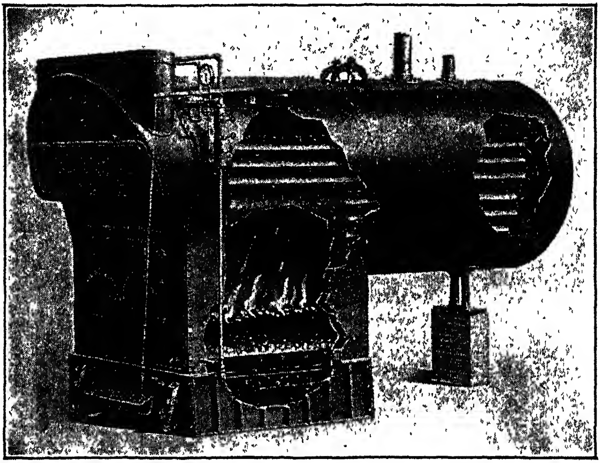


Fig. 106.—Type of tubular boiler used in greenhouse heating.

latter, water is contained in tubes about which the heated gases flow. The tubes are arranged in a variety of ways in both kinds. Some of the smaller wrought-iron boilers are constructed in a manner somewhat similar to cast-iron boilers, the fire impinging on wrought-iron receptacles containing water in thin sheets.

(Fig. 109). It is claimed for boilers of this type that they are more efficient than cast-iron and that they are free from some of the troubles of fire-tube and water-tube boilers.

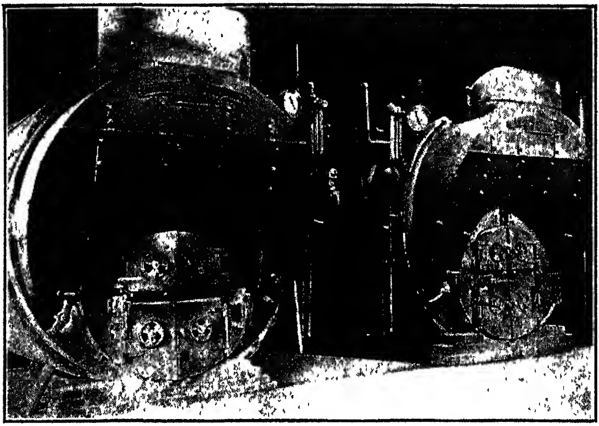


Fig. 107.—Battery of two marine type boilers used for greenhouse heating.

Steam and Hot Water Boilers.—As usually constructed the smaller, low pressure steam boilers differ but little from those used in hot water heating. In fact many makes are recommended for either purpose. When used for hot water the whole system is filled with water. When used for steam the boiler is only partly filled with water, the upper part acting as a steam chamber. When used for steam care

must be taken to see that water is kept at the proper level. Different fittings or accessories are used when the boiler is used for steam than when used for hot water. These will be described in succeeding paragraphs.

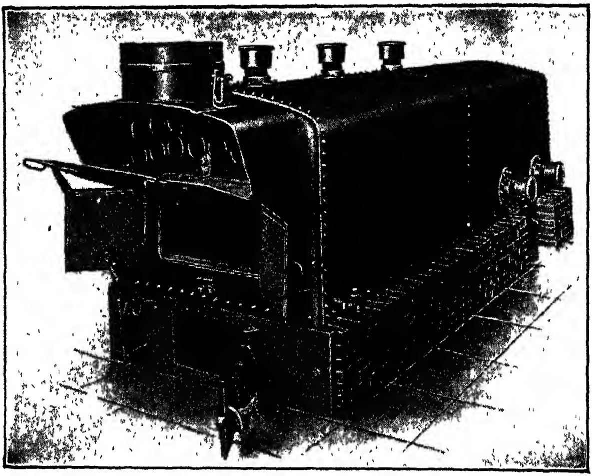


Fig. 108.—Another type of wrought-iron boiler.

Boilers for Soft and Hard Coal.—Hard coal burns with a "short" flame, and much less fire travel is required to burn the gases than when soft coal, which burns with a "long" flame, is used. More flue way is also required for soft coal and the grates are more open. Most greenhouse boilers which are designed for

soft coal will burn hard coal equally well. If they are designed primarily for hard coal they will not burn soft coal efficiently. More grate surface is required for soft coal than for hard coal, because it is more bulky weight for weight.

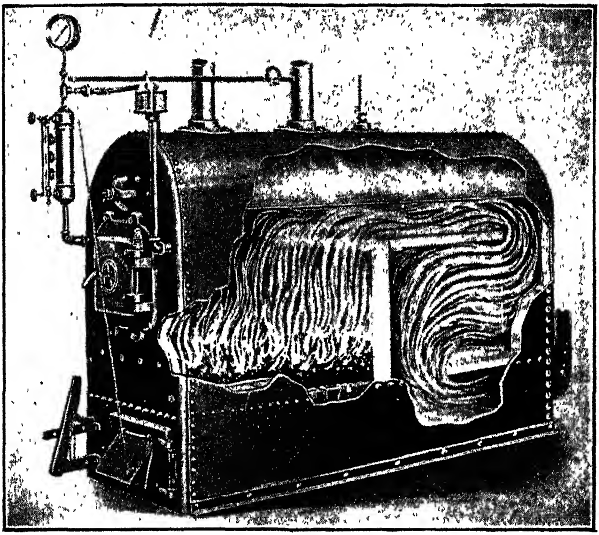


Fig. 109.—A wrought-iron boiler without flues.

Most modern greenhouse boilers will burn either hard or soft coal, but a larger size will be required for soft coal than for anthracite.

Boiler Ratings.—An approximate idea of the size of boiler needed may be found by figuring the amount of grate surface by the method

described on page 200. Boiler manufacturers, however, rate their boilers showing their capacity. Some give the number of square feet of glass that they will heat to a given temperature; others give the number of linear feet of radiating pipe of a given size which they will supply; and still others, especially the manufacturers of large tubular boilers, give the capacity of their boilers in terms of horse-power.

Since different manufacturers often question the correctness of the ratings of their competitors, it is but fair that buyers should be recommended to exercise considerable caution. Probably most boilers will, under favorable conditions, develop the number of heat units for which they are rated, but for the sake of safety and to prevent the necessity of forcing, it is best to select boilers with ratings at least 20 per cent. in excess of the theoretical needs.

When boilers are rated according to the number of linear feet of radiating pipe they will supply, it is usually given in terms of either 3½-inch cast-iron pipe or in 2-inch wrought-iron pipe. The following table gives the length of pipes of other sizes equivalent to 1 linear foot of 2 and 3½-inch pipe.

1 ft. of 3½ in. C. I. pipe equals....3.04	ft. 1	in. W. I. pipe
1 ft. of 3½ in. C. I. pipe equals....2.41	ft. 1¼	in. W. I. pipe

1 ft. of 3½ in. C. I. pipe equals	2.10	ft.	1½	in. W. I. pipe
1 ft. of 3½ in. C. I. pipe equals	1.68	ft.	2	in. W. I. pipe
1 ft. of 3½ in. C. I. pipe equals	1.39	ft.	2½	in. W. I. pipe
1 ft. of 2 in. W. I. pipe equals	1.806	ft.	1	in. W. I. pipe
1 ft. of 2 in. W. I. pipe equals	1.431	ft.	1¼	in. W. I. pipe
1 ft. of 2 in. W. I. pipe equals	1.25	ft.	1½	in. W. I. pipe

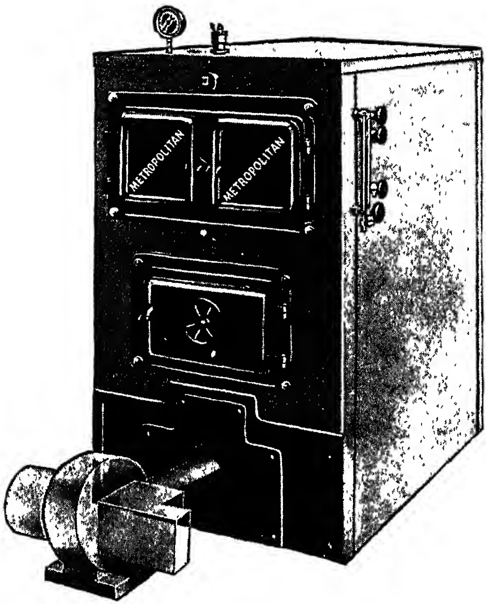


Fig. 110.—A jacketed type boiler fitted with an oil burner. May also be fitted with an automatic coal stoker.

Most boiler ratings are given for a minimum outside temperature of zero degrees, Fahrenheit. For localities subject to a temperature of 10 degrees below zero a boiler of 10 per cent.

greater capacity should be secured, and for localities subject to a temperature of 20 degrees below zero, a boiler of 20 per cent. greater capacity should be secured.

The term horse-power, as applied to boilers, represents the energy developed in evaporating 34.5 pounds of water per hour from a temperature of 212 degrees, or the development of 33,317 B. T. U. per hour. Roughly, a heating boiler will supply 100 square feet or radiation for each horse-power which it develops.

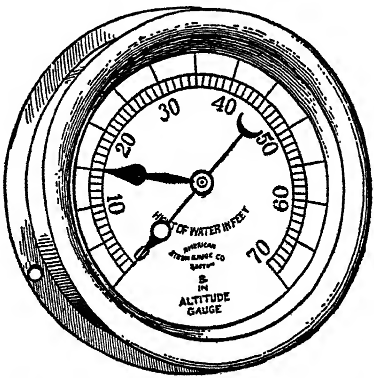


Fig. 111.—Altitude gauge for hot water boiler.

Boiler Accessories.—It has already been stated that some steam boilers may be used for hot-water heating by simply changing the fittings. When used for hot-water heating the

boiler is fitted with an altitude gauge, which shows the height of the water in the system; also with a thermometer to show the temperature of the water. A valve is provided for draining the boiler and, if desired, an automatic damper regulating device may be installed.

When used for steam heating the boiler is only partially filled with water, and a water column and gauge is necessary to indicate the height of the water. A steam gauge is also necessary to indicate the pressure; and a safety valve to automatically relieve the pressure, if it becomes too great for safety. Steam boilers are usually equipped with automatic damper regulators. They are rather more efficient than the regulators used on hot-water boilers. A drainage valve is provided the same as for hot-water boilers. Many states require that all steam boilers be equipped with a fusible plug, which is simply a brass plug with a tin core, which is screwed into a hole in the boiler near the bottom.

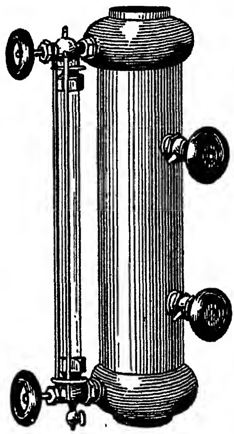


Fig. 112.—Water column and gauge for steam boilers.

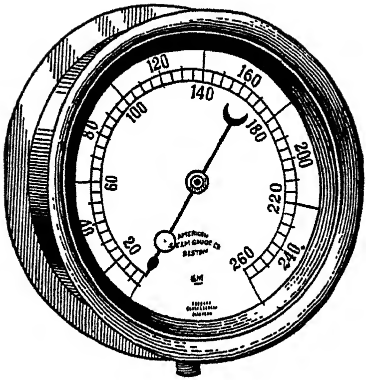


Fig. 113.—Steam gauge.

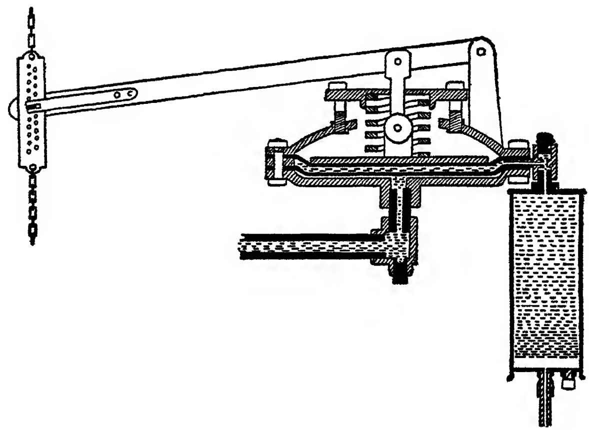


Fig. 114.—Diagram of automatic damper regulator. The steam pressure acts against a flexible diaphram which is connected with the dampers by means of a lever and chain.

If the water level falls below the plug the heat melts it out, thus making an opening and lessening the danger of an explosion.

The boiler and all pipes, except those in the greenhouse itself, should be insulated as much as possible to prevent loss of heat. The best

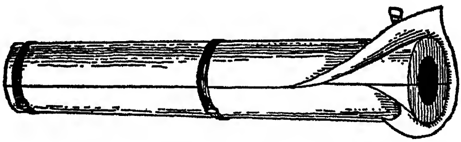


Fig. 115.—Asbestos pipe covering.

known material for this purpose is asbestos. For coating boilers it may be had in a granular form, which is mixed with water and applied with a trowel or the bare hands. For covering pipes molded casings may be had to fit all sizes of pipe.

FUELS

Coal is used almost universally for fuel in greenhouse heating, except in sections where natural gas or oil are cheap and abundant. Gas is an ideal fuel, but somewhat treacherous inasmuch as the pressure is likely to be lowest in the coldest weather.

Broadly speaking, coal is of two kinds, anthracite or hard coal, and bituminous or soft

coal. Hard coal burns with little smoke and is much heavier than soft coal, although it may not develop as much heat per ton. It is easier and cleaner to handle, and requires less atten-

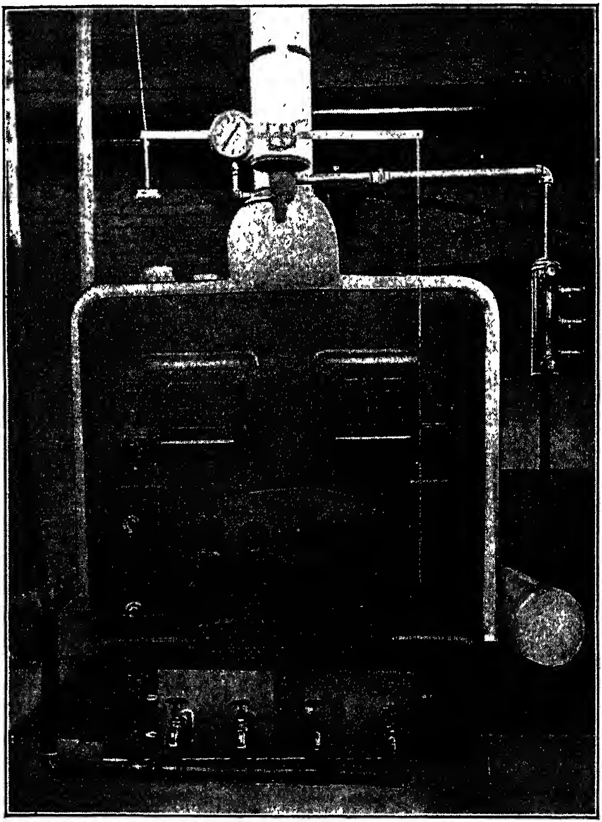


Fig. 116.—A coal boiler equipped for using natural gas.

tion in firing, but in most sections is more expensive.

Soft coals are of two general types; The free burning and the coking. The latter fuses together in burning and is somewhat more difficult to handle in the furnace than the free burning, though it is preferred by some firemen.

The heating value of a coal depends upon the percentage of total combustible matter contained, and upon the heating value per pound of the combustible portion. In some semi-bituminous coals the heating value runs as high as 15,750 B. T. U. per pound. The heating value of a few common types of coals as given by Kent are shown in the following table.

Kind of coal	B. T. U.
Anthracite	
Northern Coal field	13160
East Middle field	13420
West Middle field	12840
Southern field	13220
Semi-bituminous	
Clearfield Co., Pa.	14950
Cambria Co., Pa.	14450
Somerset Co., Pa.	14200
Cumberland, Md.	14400
Pocahontas, Va.	15070
Brier Hill, O.	13010
Scott Co., Tenn.	13700
Big Muddy, Ill.	12420
Missouri	12230

Soft coal is more commonly used in greenhouses than is hard coal. This is especially true in large establishments. The price varies with the quality, distance from the mines, etc.

Automatic Heating.—No other improvement in greenhouse heating in recent years can compare with the automatic devices now available. When equipped with thermostatic control they do away with the necessity of a full time fireman, except in large establishments. Even there the saving in labor is a substantial item. They maintain a desired minimum temperature in the greenhouse and will cease to operate when the temperature reaches a pre-determined high. However they do not do away with the necessity for ventilation as the heat of the sun on bright days may send the temperature up even when the heating system is turned off. The use of automatic ventilators will help to maintain an even temperature. (See Chapter VIII).

Where available and where a constant volume can be depended on, natural or artificial gas heating is probably the most nearly automatic. However every precaution should be taken to see that there are no leaks as gas is especially poisonous to plants. There are few sections of the country where gas, either natural or artificial, may be had at a cost to compare with coal.

Oil heating is, next to gas, the most satisfactory in ease of operation. Oil heating installa-

tions may be had which are almost 100 per cent automatic, the only ordinary care being to see that the fuel tanks are kept supplied. In most localities heating with oil is less economical than with coal though many growers feel that there is little difference when the extra labor incident to burning coal is taken into account. Even with the best arrangements coal burning involves the removal of ashes. Coal also requires more, though less expensive, storage facilities than does oil.

Automatic Stokers.—Automatic coal stokers have solved many a problem for the greenhouse operator, especially for the small operator. When equipped with thermostatic control they maintain a constant minimum temperature and in small and medium establishments do away with the expense of a night fireman.

Some of the larger types use a coal by-product known as "slack" which may be had at a relatively low cost. Most smaller stokers require for their most satisfactory operation a special "stoker" coal which at one time was much cheaper than regular furnace coal but which is now in such demand that its cost is about the same as the grade of coal used in hand firing and may be even more expensive than run-of-the-mine coal. Most stokers utilize

the under-feed principle of firing and forced draft and for this reason it is claimed that they are more efficient—that they utilize a larger portion of the fuel value of the coal—than is utilized in hand firing, and that smoke is largely eliminated.

There are several types of automatic coal stokers. They are recognized by the different mechanical methods involved in feeding the coal. In one type, coal is forced into the furnace by a plunger working in a metal tube. Considerable power is necessary, especially in the larger sizes. In another type coal is fed by gravity onto grates which are in the form of an endless chain and which run underneath the boiler, depositing the ashes at the opposite end. They also require considerable power. Both of the above types are frequently powered by steam, and are more commonly used in larger installations.

Another type feeds the coal to the furnace through a tube by means of a worm at the same time supplying air for combustion by means of a fan or blower. This is the type most commonly used for domestic heating and for small and moderate size greenhouses, though sizes for large industrial purposes are available. Stokers of this type are powered by an electric

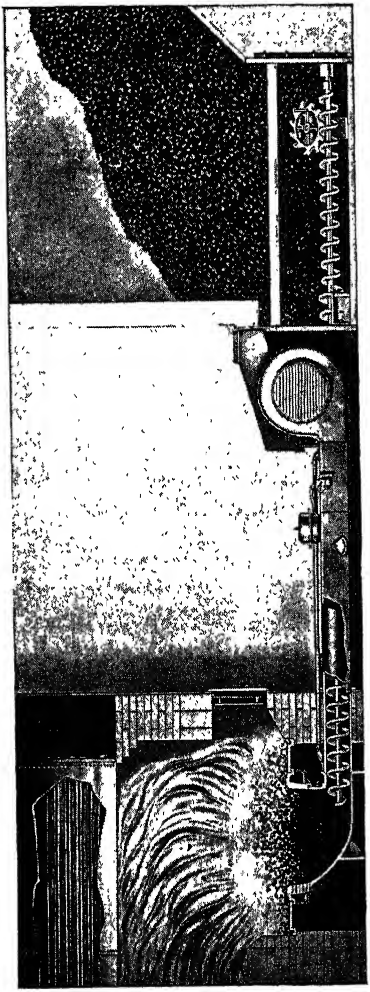


Fig. 117.—A worm type automatic stoker arranged to take coal direct from bin.—*Courtesy Iron Fireman Co.*

motor. They may be installed in almost every kind of boiler, most old boilers being adaptable without dismantling. They may be arranged so that the fuel may be taken from a hopper or they may be arranged to take fuel directly from the bin.

To guard against breakage the worm is connected to the drive shaft by means of a soft pin which shears off easily if some hard substance gets into the coal. The pin is easily and quickly replaced. At least one manufacturer makes use of a kind of automatic clutch rather than a shearing pin. It is claimed for this that it will break up many hard substances which may become mixed with the coal without injury to the mechanism.

Still another type, sometimes called pneumatic stokers, crush the coal and blow it into the firebox by means of an air blast. In this type the fuel is fed from above rather than under-fed but forced draft from below the grates is provided. These stokers are adapted to large units and will use the cheaper grades of coal including lignite.

Automatic stokers are made for both hard and soft coal. Those for hard coal use a very fine coal. This does not fuze when burned and the ash is automatically ejected by a mechanism

which may be arranged to deliver it into metal cans or bins to be disposed of at the operator's convenience. Soft coal ash fuzes into clinkers which have to be removed manually.

Though these automatic heating devices are exceedingly satisfactory it is well to remember that most of those using oil and most of the coal stokers are electrically operated. Any prolonged interruption of electric service in severe weather may well mean disaster, since it is almost impossible to hand fire boilers or furnaces so equipped. To guard against this some growers have installed small gas operated electric generators so wired that they may be substituted for the regular service in case of emergency.

Points to Consider.—The following points should be kept in mind in selecting a greenhouse heating boiler:

1. It should be of ample size—at least one size larger than is theoretically necessary.

2. The fire-box should be deep and spacious. This is especially true of boilers for small establishments where a regular fireman is not emloyed.

3. The combustion chamber (the chamber above the grate) should be large enough to insure thorough combustion of the gases.

4. The boiler should be so arranged that it may be easily cleaned, especially the flues and heating surfaces.

5. The grates should be heavy but easy to operate and easily removable, so that repairs may be made quickly.

6. The water travel should not be so circuitous as to prevent of rapid circulation.

7. There should be no packed joints. All unions should be made with push or screw nipples.

8. Soft coal burners require a somewhat different construction than do hard coal burners. The kind of fuel to be burned should be clearly in mind when selecting a boiler.

9. The ash pit should be deep and commodious. Shallow ash pits are likely to become filled so that the draft is impaired and the grate bars ruined.

CHIMNEYS AND FLUES

A very essential part of the heating equipment is the chimney or flue. Its purpose is twofold: First, to create a draft in order to furnish air to promote combustion; and second, to carry off smoke and gas. The size and height of the chimney required depends on the size of the grate surface. Mere velocity does not neces-

sarily indicate that the draft is sufficient; the chimney must be of sufficient size to carry the required quantity.

The velocity of the gas in the flue depends on the height of the flue and upon the temperature of the gas. The difference between the weight of the hot gases in the chimney, and a

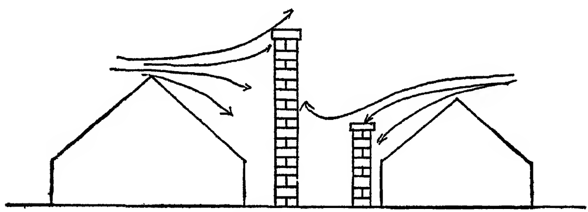


Fig. 118.—Chimneys should extend above the roofs of adjacent buildings.

column of cold air of equal size outside creates a flow upward in the chimney. This difference increases with the height of the chimney, and as the difference in temperature increases the velocity is more rapid. Locations high above sea level require higher chimneys than those near sea level, on account of the rarety of the atmosphere. For example, at Denver, Col. (5,300 feet) the height should be about 20 per cent. greater than at sea level.

Chimneys should be vertical if possible and the inside should be smooth and free from all

obstructions. They should also extend well above the roofs of adjacent buildings, particularly when there is danger of a "down draft." Round chimneys present less surface per cubic capacity than do square chimneys, and are thus more efficient. For the same reason square flues are better than oblong flues.

The following table shows the size and height of chimneys required by steam boilers. For hot-water boilers multiply the radiating surface by 1.5.

	Height of chimney in feet							
Sq. ft.	20	30	40	50	60	80	100	120
st'm rad.	Size of Chimney (dia. or 1 side sq.) in inches							
250	7.4	7.0	6.7	6.4	6.2	6.0	6.0	6.0
500	9.6	9.2	8.8	8.2	8.0	6.6	7.3	7.0
750	11.3	10.8	10.2	9.6	9.3	8.8.	8.5	8.2
1000	12.8	12.0	11.4	10.8	10.5	10.0	9.5	9.2
1500	15.2	14.4	13.4	12.8	12.4	11.5	11.2	10.8
2000	17.2	16.8	15.2	14.5	14.0	13.2	12.6	12.1
3000	20.6	18.5	18.2	17.2	16.2	15.8	15.8	14.4
4000	23.6	22.2	20.8	19.6	19.0	17.8	17.0	16.3
5000	26.0	24.6	23.0	21.6	21.0	19.4	18.6	18.0
6000	28.4	26.8	25.0	23.4	22.8	21.2	20.2	19.5
7000	30.4	28.8	27.0	25.5	24.4	23.0	21.6	20.8
8000	32.4	30.6	28.6	26.8	26.0	24.2	23.4	22.2
9000	34.0	32.4	30.4	28.4	27.4	25.6	24.4	23.4
10000	27.0	34.0	32.0	34.0	28.6	27.0	25.4	24.6
15000	...	...	38.4	36.2	35.0	33.0	31.0	29.2
20000	...	...	43.0	42.0	41.0	37.0	25.0	34.0
30000	...	...	...	50.0	48.0	46.0	43.0	41.0

CHAPTER XIV

WATER SUPPLY AND IRRIGATION

An abundant supply of water at a reasonable cost is necessary for the successful operation of a commercial range of greenhouses. Figures compiled from the experience of several growers show that the consumption of water by a vegetable crop in a greenhouse during the bright, hot days of June and July may be as high as 280 gallons per day per 1000 square feet of crops. As the watering is done over a period of not more than three or four hours per day, it is necessary to make arrangements to supply the maximum amount needed during that length of time, rather than during the 24 hours of the day as is usually figured for domestic purposes.

When city water is available at a reasonable price it is doubtful if it will pay the small grower to go to the expense of providing a private supply. Sometimes, however, the conditions are such that a private supply of water

may be had at small expense from springs, ponds or streams. In larger establishments it may be cheaper to install a private system than to depend on city water. Often, also, the ranges are located outside the city limits where city water cannot be had.

Pumps.—A variety of pumps and pumping equipment is available to suit almost every condition. They are usually operated by gas or electric motors and are adapted to pumping from deep or shallow wells or from streams or pools. Those operated by electricity are most in favor as they may be arranged more easily to operate automatically. It is advised that pressure be maintained by storage in an elevated tank rather than by means of a pneumatic tank. In this case a supply of water will be available should the pump be out of repair for a few days.

A very efficient but somewhat delicate pumping device is the combined hot-air-engine and pump. These pumps give very good satisfaction where the water is reasonably close to the surface, or when it does not have to be pumped against too great a pressure. Improved types of large size are now available, and are very economical of fuel, but the engine is not well adapted for general power purposes.

A form of pump, which is becoming quite popular for domestic use is the auto-pneumatic pump. It is designed to be used in an open well or a cased well of large bore, as the pump proper is placed entirely beneath the water. It is operated by compressed air, hence an air pump and an air tank are required. Its chief advantage for domestic purposes lies in the fact that it starts automatically when the faucet is opened, thus giving a supply of cold water direct from the well. For greenhouse purposes this is a disadvantage, as the water may be too cold to use on the plants.

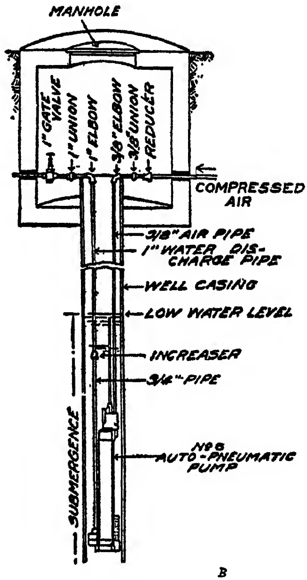


Fig. 119.—Diagram showing installation of an auto-pneumatic pump.

Pump cylinders should not be more than 20 feet above the surface of the water, as this is the limit of practical suction. When the water is more than 20 feet below the surface the

pumping cylinders are lowered accordingly. In deep wells it is common to lower the pumping cylinders well into the water.

Capacity of Pumps.—The capacity of a pump depends upon the size of the cylinder and the length and rapidity of the strokes. The table on page 233 gives the discharge per stroke in gallons, of pumps having cylinders of various sizes. This, multiplied by the number of strokes per minute, will give the capacity per minute.

Power Required.—The power required to operate a given pump may be determined as follows: Multiply the number of gallons pumped per minute by 8.357 pounds (the weight of a gallon of water). This will give the weight pumped per minute. Multiply this by the total lift in feet. This will give the number of foot-pounds of energy required per minute. Divide this by 33,000 (the number of foot-pounds in a horse-power) and the result will be the number of horse-power required. Pumping outfits are only about 50 per cent. efficient, so that the results obtained by the above are doubled in actual practice. On the average one horse-power will pump 30 gallons per minute to the height of 100 feet. In pumping water against pressure in a pneumatic tank, extra power will

TABLE OF CAPACITY OF PUMPS

Diameter of cylinder in inches	Length of stroke in inches 5	6	7	8	9	10	12	14	15	16
	Capacity per stroke in gallons									
2	.068	.082	.095	.109	.122	.136	.163	.190	.204	.218
2½	.106	.128	.149	.170	.191	.213	.255	.298	.319	.340
3	.153	.184	.214	.245	.275	.306	.367	.428	.459	.489
3½	.207	.249	.292	.333	.375	.417	.499	.583	.625	.666
4	.272	.326	.381	.435	.490	.544	.653	.762	.816	.870
4½	.344	.413	.482	.551	.619	.689	.826	.964	1.033	1.102
5	.425	.510	.595	.680	.765	.850	1.020	1.090	1.275	1.360
5½	.514	.617	.720	.823	.926	1.029	1.234	1.440	1.543	1.646
6	.612	.734	.857	.979	1.102	1.224	1.469	1.714	1.836	1.958

be required. Extra power will also be required when the water is pumped for any considerable distance, on account of the friction of the pipes. The frictional loss in feet of lift for each 100 feet of pipe of various sizes is shown in the following table.

Gallons per min.	Size of Pipe ¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.
	Frictional Loss					
10	29.9	7.3	1.4	1.0	0.28	0.09
15	66.0	16.1	5.5	2.2	0.57	0.18
20	115.0	28.0	9.5	4.8	0.96	0.32
25	179.0	43.7	14.7	6.0	1.7	0.48
30	264.0	63.2	21.0	8.6	2.1	0.69
35	372.0	85.1	28.9	11.6	2.7	0.92
40	461.0	110.0	37.0	14.9	3.7	1.2

This loss by friction cannot be disregarded. Suppose, for example, it is desired to deliver 20 gallons per minute at a distance of 100 feet. By referring to the above table it will be seen that if a ¾-inch pipe were used, a loss equal to a head of 115 feet would be sustained, while if a 1½-inch pipe were used a loss of only 4.8 feet would be sustained. It is economy to use pipe of generous size.

Hydraulic Rams.—The hydraulic ram is a device which utilizes the force of water, falling a short distance, to elevate a portion of the water to a greater height. It is wasteful of water, but when a never-failing stream of suf-

ficient flow and fall is available it is one of the most economical and satisfactory of water-lifting machines.

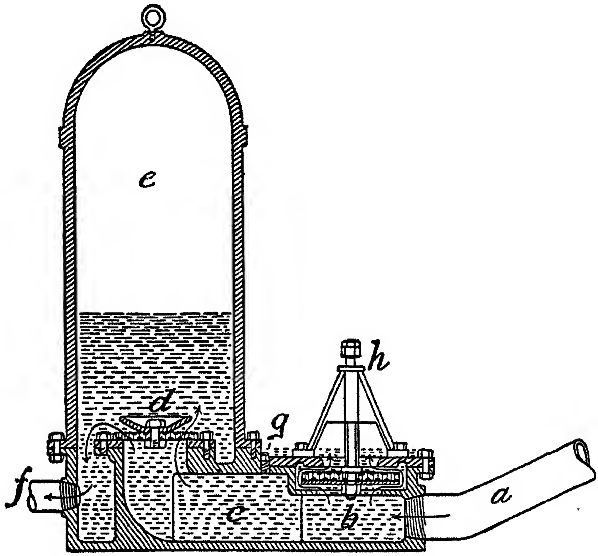


Fig. 120.—A simple type of hydraulic ram. a, intake pipe; f, delivery pipe.

Rams are somewhat difficult to install by a novice, because of the rather exacting conditions necessary to secure the most efficient service. When they are properly installed, however, they give little trouble, provided they are kept from freezing.

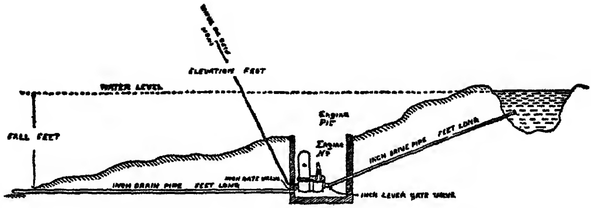


Fig. 121.—Plan for installing a hydraulic ram.

Capacity of Rams.—To find the capacity of a ram for any given conditions proceed as follows: Multiply the fall in feet by the quantity of water which may be supplied to the ram in gallons per minute, and divide the product by the height the water is to be raised. The result will be the number of gallons delivered per minute. The above disregards loss by friction and assumes that a ram of the proper size is installed.

By use of the table on page 237 an estimate of the capacity of a ram for different conditions may be determined. The left-hand column indicates the number of feet of fall possible to secure, and the numbers at the top of the vertical columns indicate the height to which water is to be raised.

For example: Suppose we have a stream with a flow of 100 gallons per minute; that there is an available fall of 10 feet, and that it is desired to raise the water 40 feet. The factor

ESTIMATED CAPACITY OF RAM FOR DIFFERENT CONDITIONS

Power head in feet	Pumping head in feet 10	15	20	30	40	50	60	70	80	90	100
5	540	345	240	160	120	96	80	69	60	53	43
6	...	432	302	192	144	115	96	82	72	64	57
7	...	505	378	235	168	134	112	96	84	75	67
8	...	...	432	270	192	154	128	110	96	86	77
9	...	...	485	300	216	173	144	124	108	96	86
10	...	...	540	360	252	192	160	137	120	107	96
12	...	...	...	430	301	230	192	165	144	128	115
14	...	...	...	505	353	270	224	192	168	150	135
16	...	...	...	...	432	323	257	220	192	171	154
18	...	...	...	...	486	390	303	247	216	192	173
20	...	...	...	...	540	430	336	288	240	214	192
22	...	...	...	...	...	475	370	303	264	235	212
24	...	...	...	...	...	520	405	346	288	256	230
26	...	...	...	...	...	...	470	375	328	278	250
28	...	...	...	...	...	...	505	430	354	300	269
30	...	...	...	...	...	...	540	465	405	336	288

To use: Multiply the factor opposite power head and under pumping head by the number of gallons of water available per minute. The product will be the number of gallons delivered per day.

in this case (252) will be found in the column headed by 40 and opposite the number 10 under power head. Multiplying 252 by 100, we have 25,200, the number of gallons that may be delivered per day by a ram of the correct size.

In ordering a hydraulic ram the following information should be given:

1. Flow of water in gallons per minute.
2. Vertical fall in feet.
3. Distance in which fall is obtained.
4. Vertical height above ram the water is to be raised.
5. Distance water is to be forced.
6. Number of gallons required per day.

Double-acting rams which will utilize the water from a creek or river as power and pump water from a spring or shallow well may be had, but they are somewhat more complicated.

Windmills for Pumping.—The chief objection to the windmill for pumping is its lack of dependability. Where the wind is fairly constant, or when a large storage capacity may be had cheaply, windmills are the cheapest source of power. On the average the windmills used for pumping develop about three-fourths horsepower. The geared steel wheel mills are more efficient and will run in lighter winds than will the wood wheel mills.

Storage Tanks.—Storage tanks are necessary with private water systems, to insure a constant supply and to furnish pressure. They fall naturally under two heads: (1) Open tanks in which pressure is obtained by gravity; (2) closed tanks, containing air into which water is forced, the compressed air in this case furnishing the desired pressure.

In placing tanks in the attic, or other elevated positions, it is well to keep in mind the weight of water and to see that the supports are amply strong. For example, a 10-barrel tank of water will weigh, in addition to the tank itself, more than one and a quarter tons.

The pressure to be obtained from elevated tanks depends upon their elevation, each additional foot giving a pressure of about 0.433 pounds per square inch. The following table shows the pressure (disregarding friction) to be obtained at various heights.

Height in feet	Pressure per sq. inch	
10	4.33	pounds
20	8.66	"
30	12.99	"
40	17.32	"
50	21.65	"
60	25.98	"
70	30.31	"
80	34.64	"
90	38.97	"

Capacity of Storage Tanks.—The capacity of storage tanks is not difficult to arrive at by simple mathematics, unless they are of unusual shapes. For convenience, tables are given below showing the capacity of round and square tanks of standard sizes. When pneumatic tanks are used, about a third of their capacity is occupied by the compressed air.

TABLE SHOWING CAPACITY OF ROUND STORAGE TANKS

Diameter Feet	Height Feet	Capacity Gallons	Diameter Feet	Height Feet	Capacity Gallons
4	4	378	5	6	735
4	5	470	5½	8	1400
4	6	567	6	2	423
4	8	756	6	2½	528
5	3	440	6	3	635
5	4	588	6	4	845
5	5	735	6	5	1056

TABLE SHOWING CAPACITY OF RECTANGULAR TANKS

Width Feet	Height Feet	Length Feet	Capacity Gallons
2½	2½	8	378
3	2	8	360
3	2	10	448
3	½	8	448
3	2½	10	565
3	3	10	673
4	2	8	478
4	2	10	598
4	2½	8	598
4	2½	10	748
4	3	8	718

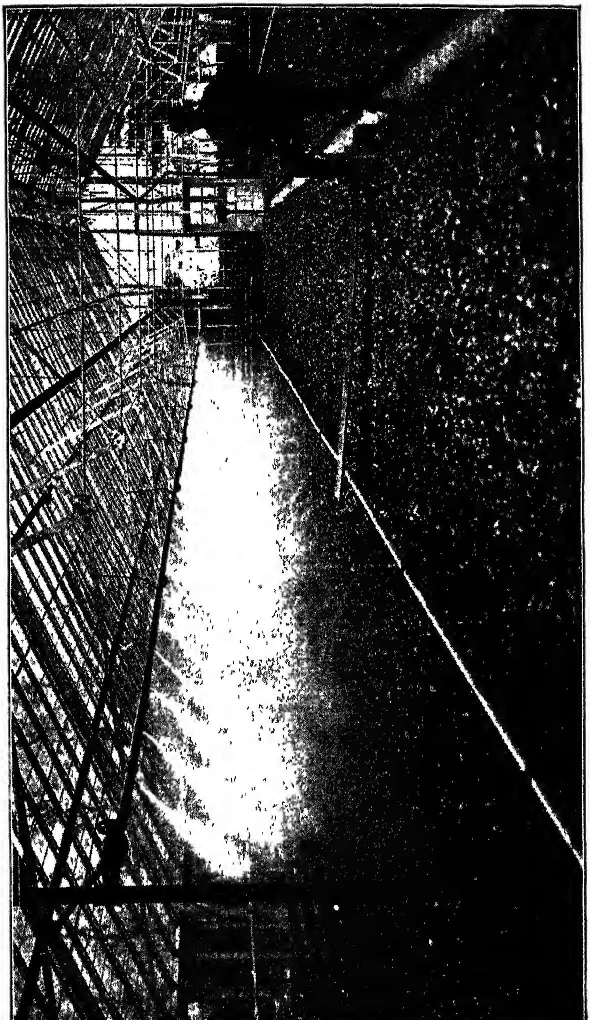


Fig. 122.—Overhead irrigation.

IRRIGATION

There are two general methods of watering greenhouse crops aside from hand watering. One is an over-head method and the other an under-ground or sub-irrigation method. Of these the over-head system is by far the more popular. There are many kinds of over-head watering systems on the market each claiming some particular advantage or adaptation to special conditions. In general they are more commonly used when plants are grown in beds than when grown in benches. The most popular systems are those in which pipes run lengthwise of the house and are fitted with spray nozzles so spaced as to give an even distribution of a fine rain-like spray. Most have automatic devices which turn the pipes slowly from side to side so as to cover the area on both sides of the pipe. A pressure of from 10 to 30 pounds per square inch is necessary for their operation.

Sub-irrigation, when used at all, is more common when the plants are grown on benches. A bench arranged for sub-irrigation is shown in figure 123. Advocates of sub-irrigation claim that plants so watered grow better and that they are less subject to disease, particularly stem and crown rots. This system of watering

is not widely used, partly because of the construction expense involved. No water pressure is required.

A method of automatic sub-irrigation has recently been developed which may prove of value as it is not only automatic in action but

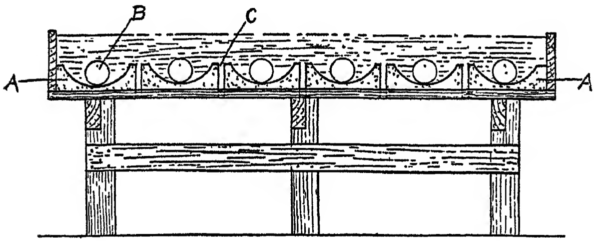


Fig. 123.—Greenhouse bench arranged for sub-irrigation. A, cement troughs on bottom of bench; B, drain tile or perforated pipes for supplying water; C, drainage spaces between troughs.

applies water whenever the soil reaches a certain stage of dryness.* This is accomplished by means of a soil tensiometer connected with a vacuum gauge which indicates the moisture content of the soil and operates a relay switch which in turn opens a valve to admit water when the soil becomes dry. Unfortunately this mechanism does not operate in reverse; this is, the tensiometer does not operate to close the

* Bulletin 793 New York State Experiment Station.

valve when the soil has become sufficiently moist. This is overcome by a clock arrangement which may be set to close the valve after the water has run for a certain length of time, the length of time necessary to achieve the proper amount of moisture having been determined before hand by observation.

CHAPTER XV

CONCRETE CONSTRUCTION

Concrete is a combination of Portland cement, sand, crushed stone or gravel and water, thoroughly mixed and then allowed to set or harden.

Portland cement, or cement, as it is commonly known, is manufactured by burning and grinding together limestone and clay, or shale, in certain proportions. It derives its name, Portland cement, from its resemblance to Portland stone. It is also sometimes known as hydraulic cement, or building cement.

Concrete has wellnigh revolutionized building practice, but in no case has it displaced masonry to a greater extent than in greenhouse construction. Formerly, the walls of a greenhouse were a source of much trouble, because of their rapid deterioration, but it was found that when concrete was used they became the most stable part of the structure. Concrete is practically the only material now used for the

foundations and walls of commercial greenhouses.

Cement is shipped in sacks holding 95 pounds or approximately seven-eighths of a cubic foot. It is sometimes quoted by the barrel, this meaning four sacks or 380 pounds. Specifications for concrete are sometimes made in terms of the number of barrels of cement required, or in terms of cubic feet, rather than in the number of sacks.

Sand.—Sand, to give the most satisfactory results, should be free from clay or organic matter, and rather coarse. Very fine sand will require a greater proportion of cement and as a consequence the concrete will be more expensive. In a small way, sand that contains some organic material may be washed and thus made satisfactory. Washed sand and gravel may be had of most large dealers.

Stone.—Either crushed stone or gravel may be used in making concrete, the only difference being that the crushed stone usually has a cleaner surface and the cement will cling to it more tightly. When gravel is used it should be free from clay, and the individual stones should be clean and bright and not covered with a layer of clay or soil.

The size of the stones may range from a

fourth to two and a half inches in diameter, the size depending on the use to which the concrete is put. The best results are obtained when the sizes vary regularly from small to large, in order that they may settle well together when the concrete is poured.

Run of the Bank gravel is sometimes used. This is economical only when it contains sand and gravel in the correct proportions, as explained in a succeeding paragraph.

Crushed Stone may also contain very fine, medium and coarse stone in the correct proportions, so that no sand need be added, but such a condition is rare, unless the stone is ground and furnished for this special purpose.

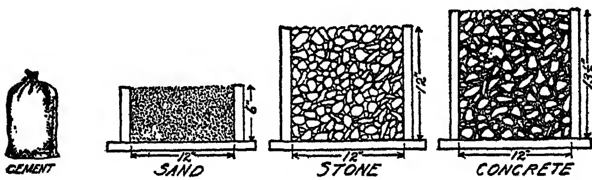


Fig. 124.—Proportions of cement, sand and stone required to form concrete.

Proportions of Materials.—Theoretically, the ideal concrete is a mixture in which all the spaces between the stones or gravel are filled with sand, and all the spaces between the grains of sand are filled with cement. From this it will

be seen that the total bulk of concrete would not be greatly in excess of the bulk of stone or gravel, as the sand and cement go to fill the vacant spaces (voids). This is really true except that, as usually proportioned, a slight excess of cement is allowed. This is wise in order to insure that there shall be a film of cement about each stone and grain of sand, so they may be all bound together in a solid mass.

The common formula for most concrete work is known as the 1:2:4 mixture. In this there are: 1 part by measure of cement, 2 parts of sand, and 4 parts of stone or gravel. This is the formula commonly used for walls above ground and for bridges and similar work. For sidewalks, floors, etc., which are supported on a firm foundation and are not subjected to heavy strain, a weaker mixture of 1 part of cement, 2¼ parts of sand and 5 parts of stone or gravel, is sometimes used.

For plastering the outside of walls and for similar purposes a mixture of cement and sand alone in the proportion of 1 to 1 is used, as it is easily worked and leaves a smooth surface.

Mixing.—For small jobs concrete is usually mixed by hand. The essentials are: (1) A tight platform or mixing board of sufficient size; (2) a convenient measuring box; (3) suitable

shovels; and (4) a supply of water. Quite commonly the sand and gravel is measured in the wheelbarrows in which it is hauled, a little experience, secured by carefully measuring the amount for a few times, being all that is necessary to insure sufficiently accurate measuring. The barrow loads are checked up from time to time, however, to see that they are not overrunning or falling short.

For anything but small jobs the use of a portable, power driven mixer is advised. Power mixers are not only economical of time and labor but are likely to deliver a better mixture than is usually made manually. Ready mixed concrete delivered on the job ready to pour is a great convenience appreciated by those located where this service is available.

It is convenient to mix in batches requiring even bags of cement. For example, two bag batch would mean two bags of cement, a quantity of sand equal to 4 bags (3¾ cubic feet) and 8 bags (7¼ cubic feet) of stone or gravel. They are mixed together thoroughly, shoveling over several times before adding the water.

Amount of Water.—The quantity of water used has but little effect on the resulting concrete, the amount depending rather on the con-

sistency at which the concrete can best be handled for the special purpose for which it is to be used. The dryer the mixture the more quickly it will set.

For thin walls, or where the form contains many indentations, the mixture should be thin enough to run off the shovel quickly in handling.

For walls of medium thickness (6 to 12 inches) or for floors, walks, etc., it should be jelly-like in consistency, so that it will pile up somewhat on the shovel, but will slowly settle and run off the sides.

For foundations, underground, where it is important that the mixture set quickly, it may be mixed so dry that it will handle like damp earth. Care must be taken in making this "dry mixture" that every part is moistened.

Estimating Materials.—The quantity of cement, sand and gravel necessary for a given piece of work may be found by multiplying the number of cubic feet by the percentage of cement, sand and gravel in a cubic foot of the mixture to be used. For convenience these proportions are given in tabular form in terms of barrels of cement and cubic yards of sand and gravel.

TABLE SHOWING PROPORTIONATE QUANTITIES OF CEMENT, SAND AND GRAVEL IN A CUBIC FOOT OF CONCRETE

Mixture	Cement barrel	Sand cubic yard	Stone or gravel cubic yard
1:2 :4	0.058	0.0163	0.0326
1:2½:5	0.048	0.0176	0.0352

To use, multiply the number of cubic feet of concrete required by the factor shown in the table. The result will be the quantity of the material required.

For example, 1000 cubic feet of 1:2:4 concrete would require

1000 x 0.058 or 58 barrels of cement

1000 x 0.163 or 16.3 cubic yards sand

1000 x 0.0326 or 32.6 cubic yards gravel

In estimating for cement mortar, figure 1 cubic foot to each 15 square feet of surface to be covered. Each cubic foot of 1:1 sand and cement mortar requires 0.1856 barrels of cement and 0.0263 cubic yards of sand.

Forms.—As concrete is soft when mixed, it is necessary to have some kind of a form or mold to hold it in the desired form and position until it hardens. For foundations, for such structures as greenhouses, a trench is usually dug 12 or 14 inches wide, and deep enough so that the bottom will be below the frost line. If the soil is firm enough to hold its place no form

will be needed, but the concrete may be poured directly into the excavation, tamped and allowed to harden.

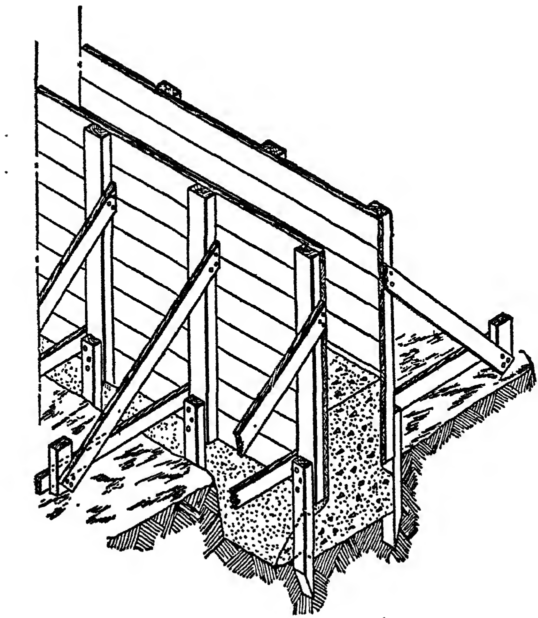


Fig. 125.—Form for a concrete wall.

For that part of the wall which is above ground, however, a form is needed. It is important that this form be vertical, that it be straight, and that it be smooth in the inside so that the resulting wall will be agreeable to the

eye. The making of the forms is important. They should be built by an experienced carpenter.

Any kind of lumber which is free from knot holes and has been surfaced to an even thickness will answer for forms. If the wall is a high one it may be necessary to tie the sides of the form together with wire. The wires remain in the concrete when the form is removed, but may be cut off flush with the surface, and if the wall is plastered they will not be noticed.

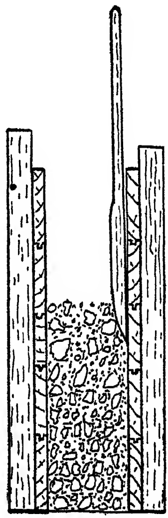


Fig. 126.—Method of facing a concrete wall.

Filling the Forms.—In filling the form the concrete is placed in layers about 6 inches deep and tamped lightly until water shows on the surface. This will insure its settling together closely. If the wall is not to be plastered and a smooth surface is required, a spade or paddle is run down all along between the concrete and the sides of the form when the concrete is poured. This will force the larger stones toward the center of the wall and allow the smaller stones and sand to fill in

next to the form, thus making a smooth surface.

Reinforcing.—Concrete will withstand enormous crushing loads, but in walls where there is a considerable side strain, it should be reinforced with iron or steel. The best materials for this purpose are iron or steel rods. If they are twisted or roughened in some manner, so that the concrete will adhere to them tightly, their efficiency will be greatly increased. They are put in the forms, usually vertically, about midway between the sides and 2 or 3 feet apart before the concrete is poured.

When an extra strong wall is required rods may be laid horizontally as well as vertically on the top of every layer or every second layer as the concrete is placed and tamped down into the soft mixture. When the walls extend only 3 or 4 feet above the surface and are at least 8 inches thick as is commonly the case in greenhouses, little if any reinforcement is needed.

Walks and Floors.—Concrete walks are now very commonly used in commercial as well as private greenhouses, and the boiler and service rooms are usually floored with concrete. As the walks are not usually subject to as hard usage as those laid out-of-doors, or to the action of frosts, it is not necessary to make

them quite as thick, but in other respects they differ but little from concrete sidewalks.

The common method of building walks in a greenhouse is to make an excavation a few inches deep and as wide as the walk is to be and fill it with broken stone, pieces of brick, etc., to make a foundation. On top of this, two

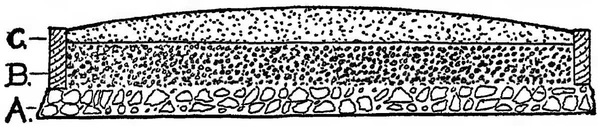


Fig. 127.—Structure of a concrete walk. a, foundation; b, coarse concrete; c, finish coat of fine concrete.

pieces of straight 2 x 4-inch lumber are placed on edge, level with each other and with their inside edges spaced just as far apart as the walk is to be wide. They are then fastened by driving stakes on the outside and nailing. The concrete is then poured into this form to within about an inch of the top and tamped firmly. A top coat, usually of finer material, is then placed on top of the first layer before it is set, and struck off by running a straight edge along the tops of the side pieces. This is then troweled by hand to give a smooth and slightly curving surface.

To allow for expansion and contraction, the

walk should be cut into blocks before it sets. This may be done by putting in pieces of thin sheet-iron at regular intervals to be removed when the concrete has partially hardened. Sometimes the walk is cut through with a spade while still soft, at regular intervals and fine, dry sand placed between the blocks so made. This is usually quite satisfactory and by careful troweling a very neat walk may be made in this way.

For the lower layer, when there is a firm foundation, a 1:2½:5 mixture will be satisfactory. The top layer should be of a 1:2:4 mixture or, when an especially smooth surface is required, of a 1:2 mixture, that is, one part of cement and two parts of sand.

Floors are laid practically the same as walks, except that they are usually troweled level instead of curving. The work is begun at one side of the floor, and as soon as one section has been laid and has had time to set, the side boards are taken up and put down for the next section. Floors should seldom or never be laid in a solid mass.

Waterproofing.—Much trouble is often experienced in underground boiler rooms from water. The best protection is to lay a row of tile completely around the outside of the foun-

dation, at the bottom, and connect it with the sewer or drain. If the bottom of the cellar is springy it may be necessary to lay the floor in a solid piece and in two layers. After the first layer has set and become dry, or nearly so, a thick coating of hot tar may be applied, allow-

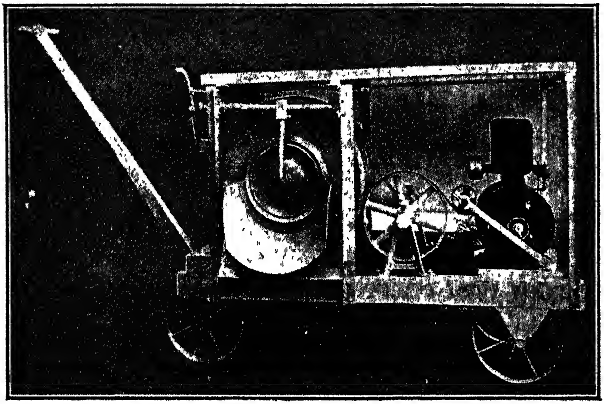


Fig. 128.—A small power machine for mixing concrete.

ing it to extend for a few inches up the side walls. When this has hardened put on another coat of rich concrete, troweling it up the sides as far as the tar has been placed. When an absolutely watertight job is required it may be necessary to coat the entire outside surface of the walls with tar and then bank up with earth.

Several so-called waterproofing materials

designed to be placed in the concrete when it is mixed are on the market.

Concrete Blocks.—Blocks made of concrete in special molds or forms are sometimes employed for walls. They are usually hollow and for that reason make a warmer and somewhat dryer wall than does solid, poured concrete. Experience shows that as a rule they are less durable than solid walls, but when the cost of material and labor for making forms is considered they may be more economical. They are often made with an ornamental face resembling broken stone, and make a somewhat more pleasing appearance than a plain wall.

Cost of Concrete.—So many factors enter into the cost of concrete that no reliable general estimate can be given. The price of cement is fairly constant. The cost of sand and gravel or crushed stone, on the other hand, differs widely. In some places it may be had on the premises, in others it may have to be transported for several miles. Other factors entering into the cost are labor and the size of the operation. Where the quantity of work will justify the use of a power mixing machine, the cost is usually less than when the mixing is done by expensive hand labor, although the cost

for labor may often be greatly reduced by carefully planning the work.

In general the contract prices for walls on comparatively small jobs range from 7 to 20 cents per cubic foot, and for walks and floors from 4 to 15 cents per square foot.

CHAPTER XVI

PLANS AND ESTIMATES

The cost of any kind of a building must necessarily vary with the cost of building material and the price of labor. This is especially true with greenhouses, since the materials used (glass especially) are subject to extreme fluctuations in price. In the preceding chapters it has been the aim to give all the data necessary for estimating the amount of material required for any given house, but no attempt has been made to state definite prices.

Little can be added in this chapter to what has already been given, and it would be useless repetition to collect the data into one chapter, as it may be easily found by referring to the index. An effort has been made, however, to make some suggestions as to the probable cost of different types of houses under varying conditions.

Basis of Estimates.—Since the economic value of a greenhouse depends on the area of

surface covered (bench space) it is common to estimate costs in terms of square feet of surface covered. In an investigation among a large number of growers (all types of houses) the author found that the first cost averaged not far from 45 cents per square foot of surface under glass. This included cost of heating system, but did not include cost of service buildings.

The cheapest plant on which data was secured was a range of four all wood frame houses, 16 x 50 feet, which had been in service for nine years and which was built at a cost of $525, or about 22 cents per square foot. In this case a second-hand boiler was used. Several larger ranges heated by steam from a central heating plant have been built at a cost of between 30 and 40 cents per square foot, though at a time when material was low in price. Data on modern semi-iron construction, when the labor was performed for the most part by the owner and his help, show a cost of between 50 and 60 cents per square foot, and all iron construction between 60 and 75 cents per square foot. All these, of course, were standard commercial houses. Private and public conservatories and ornamental houses often cost two and three times as much.

Detailed Estimates.—Detailed estimates necessarily differ with the grade of material used. The following is a detailed statement of the material used for and the cost of a semi-iron frame house 30 x 90 feet, not including labor of erecting.

850 cubic feet concrete (wall and piers)—	
50 barrels cement	
14 cubic yards sand	
28 cubic yards gravel	$100

PIPE

Side Posts—	
32 pieces 2-inch pipe, 5 feet 6 inches	
Purlins—	
360 feet 1¼ inch	
Purlin Supports—	
24 pieces 1½-inch pipe, 8 feet 3 inches	
24 pieces 1½-inch pipe, 11 feet	
Cross Ties—	
24 pieces 1¼-inch pipe, 5 feet	
24 pieces 1¼-inch pipe, 8 feet 6 inches	
Pipe and fittings for water lines, 100 feet ¾ inches	$75

PIPE FITTINGS

32 Gutter brackets	
120 Clamp fittings	
48 Foot pieces	
140 Purlin clasps	$30

MILL WORK

240 feet sill
180 feet eave plate
90 feet ridge
180 feet drip gutter
4 pieces gable rafter, 18 feet long
268 pieces sash bars, 18 feet long
4 pieces corner bars, 4 feet long

268 pieces glazing bars, 4 feet long	
180 feet sash header	
330 feet glazing bar	
100 feet 2 x 4 for door casing and gable bracing	
1 door	
Ventilator sash with stops	$200

GLAZING

86 boxes glass (16 x 24)	
500 pounds putty	
8000 glazing points	$250
Ventilating apparatus	25
Nails and other hardware	25
Paint	50
Freight	50
Miscellaneous items	25

HEATING

Boiler (hot water)	
Pipe and fittings	
Brick for flue	$550
Total	$1345

This house covers approximately 2700 square feet of surface, which at a cost of $1,345 gives a cost per square foot of 49.81 cents for materials, but not including labor.

Figures on a similar house 31 x 100 feet submitted by a well-known manufacturer of greenhouse materials are given below:

WOODWORK

200 feet gutter with drip
100 feet ridge
228 feet glass sill
175 feet gable end bars

4 pieces gable rafters, 18 feet long	
144 pieces sash bars, 18 feet long	
12 ventilators	
12 pieces ventilator sash cap	
60 headers	
144 side bars	
4 corner bars	
1 door	$177.01
Ventilating machine complete	26.40
Hinges for ventilators	3.60
Trussing material	5.20
Hardware for doors	.63

PIPE, POSTS AND FITTINGS (walls)

40 pieces 2-inch, 5 feet long	
40 pieces post tops	$ 27.20
Nails	2.50
10 pounds glazing points	1.30
400 pounds putty	14.00
Paint	32.00
Glass, 4600 square feet	260.00
Purlins, fittings and purlin supports	61.75
Gable bracing material	2.50
Heating plant complete	703.33
Total..................	$1317.42

The latter estimate does not include cost of materials for foundations, but in other ways is complete. The cost per square foot of surface covered is 43.9 cents not including cost of erection.

Materials for iron and steel frame houses, complete above foundation, except for heating equipment, and ready for erection are currently quoted at from 40 to 70 cents per square foot of

soil surface area. This does not include cost for transportation or cost of erection.

For an all wood frame house the cost of material will probably be from 15 to 25 per cent. less than the above and the cost of erection from 10 to 20 per cent. less.

For an all metal frame house the cost for materials will range from 25 to 40 per cent. greater than for the semi-iron construction, but the cost of erection will be less.

The foregoing figures and estimates of costs were accurate at the time they were made but cannot be relied upon to remain constant over a period of years or even from season to season on account of the variation in cost of labor and materials. Prospective builders will of course obtain estimates from competent contractors before embarking on a building program.

Information Required for Estimates.—Manufacturers of greenhouses will gladly give estimates of the cost of a greenhouse, either erected or for materials only, to those seriously contemplating building. In writing the following information should be given:

1. Type of house (semi-iron, all metal, etc.).
2. Kind of roof (even span, three quarter span, etc.).

3. Length and width (if range, send sketch showing arrangement).
4. Height to eaves.
5. Pitch of roof or height to ridge.
6. Size of glass preferred.
7. Kind of heat (hot water, steam, vapor).
8. Temperature to be maintained.
9. Coldest outside temperature expected.
10. Kind of fuel.

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